DEPARTMENT OF THE INTERIOR, CANADA

HON. ARTHUR MEIGHEN, Minister. W. W. CORY, Deputy Minister.

GEODETIC SURVEY OF CANADA

NOEL OGILVIE, Superintendent

ANNUAL REPORT

OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1918

1917/18

OTTAWA
J. de LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1919

70-foot signal tower near Kemptville, Ontario.

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44259—1½

Geodetic Survey

Roll of Honour

J. McDonnell
*O. M. Stitt
G. H. McCallum
G. S. Raley
*F. M. Badham
J. M. Riddell
J. W. Menzies
*W. S. Burns
D. H. Nelles
J. H. Kihl
*E. M. DesBrisay
C. K. McElroy
E. W. Nesham
*A. A. Lewis
O. Drury
G. F. Dalton
*A. L. Lindsay
W. C. Murdie
M. R. Byron
*A. MacIntosh
*F. W. King
J. E. Ratz
*D. V. Ritchie
H. P. Moulton
*Kimball Keeping

*Killed in Action.

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REPORT OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA.

W. W. Cory, Esq., C.M.G.
Deputy Minister of the Interior,
Ottawa.

Sir,—I have the honour to submit the following report on the operations of the Geodetic Survey of Canada for the year 1917, together with the attached summaries of reports of the officers in charge of the various sections of the work.

Functions of a Geodetic Survey

The Geodetic Survey of Canada is the outcome of a realization of the great economic value to this country of a geodetic survey to control the accuracy of its logical successors, topographic and hydrographic surveys, and to co-ordinate the results of older surveys.

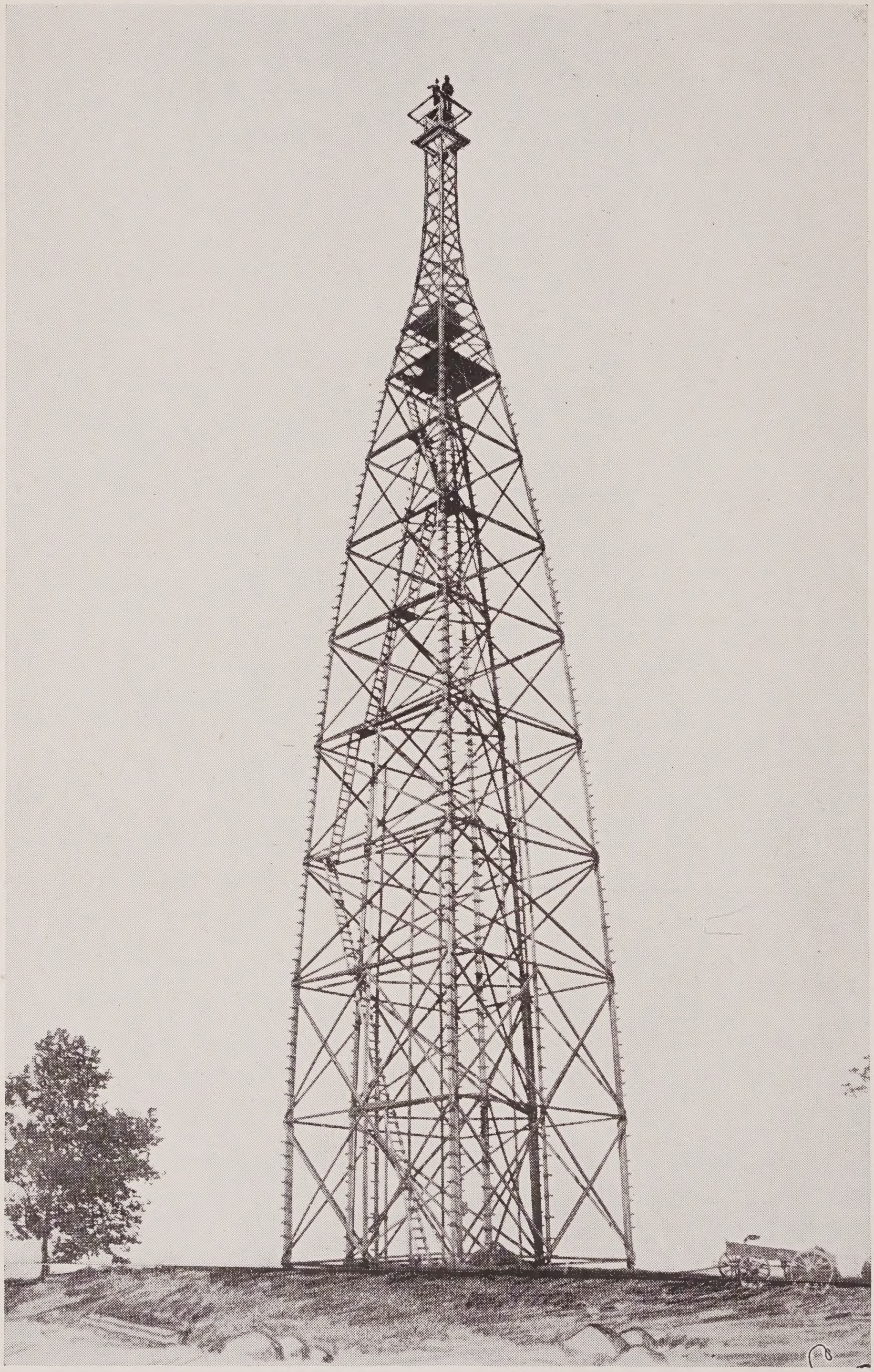
It has as its function the obtaining of the geographical position of points scattered over our country, together with its coast lines and large waterways. It is the foundation of the work of producing accurate maps of our country, the necessity of which is easily comprehended by all.

Triangulation

Triangulation and precise levelling are the branches of geodectic work which have the greatest commercial and economic value. The precise levelling operations are explained on page 22 and, in order that triangulation operations may be better understood, a brief and elementary explanation of the principles will be given.

The principles of a triangulation survey rest on the well-known fact that the earth's surface is not plane, but spherical. In the surveying operations with which most of us are familiar, the earth's surface may be considered a plane. Such an assumption may be made where the area to be covered is even as large as several hundred square miles.

In the survey of a farm or park the familiar methods of plane surveying are used. The distances may be obtained by the use of a steel tape or chain, while the angles are read with an engineer's transit. The errors to which these methods are subject are not great enough to materially affect the accuracy which is required.



147-foot Tower near Chatham, Ont., with Lamp-stand extended 37 feet.

When the survey of one or more provinces is required, however, the consideration of the earth's shape and size, as well as the limitations of direct linear measurements, require the use of triangulation principles in order that accuracy over the whole country may be secured. Such a survey is called a geodetic survey.

Just as one would use a long chain or tape rather than a foot rule to measure the size of a farm, so in getting distances over a large country the Geodetic Survey of Canada selects stations many miles apart on prominent hills, or, in the case of a comparatively flat country, hills on which to erect towers in order to raise the instruments with which the observations are made above woods, houses, or other obstructions. These stations are intervisible and form the angular points of a system of triangles over the country, the sides of which may be anywhere from ten to a hundred miles long. One of these triangle sides is selected as a base line whose length is very accurately measured with invar tapes.[1]

These stations are permanently marked by copper bolts set in solid rock or blocks of concrete. The angles of the triangles are then measured with a large theodolite such as those shown on pages 13 to 20 like a very precise engineer's transit.

Now, having the length of our base line, together with the angles of all our triangles, we may use the principles of trigonometry to compute the other sides of our triangles and thus obtain the accurate distances between any two of our triangulation stations much more economically than by any other system of measurement, and much more accurately than by any but the most costly methods.

From these stations also, by methods similar to those described above, the correct position of church spires, lighthouses, prominent buildings, etc., is obtained, and thus a system of accurately defined points is provided for the surveyor or engineer who makes topographic, hydrographic or other maps. Also, since the position of land survey posts close to the triangulation stations is always determined, where possible, the exact position of previous land surveys with respect to one another and to subsequent surveys is obtainable, and these surveys may be used in compiling accurate maps.

We will deal with but one more operation. The most convenient manner of describing the position of the triangulation stations is by giving their latitude and longitude. Latitudes are measured north or south from the equator, while longitudes are measured east or west from the meridian which passes through Greenwich, England. The latitude and longitude of any triangulation station, together with the direction to any other, may be very accurately obtained by astronomical observations—subject to certain errors which are explained on page 31, which, however, are not errors in the observations themselves—and, when we know the latitude and longitude of any point of our triangulation system, and the direction (azimuth) to any other station, we may compute the latitude and longitude of all of our stations, church spires, lighthouses, etc., together with their azimuth from any other station, by means of the angles and distances of our triangulation system.

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[1] For a short description of base-line measurements, see page 50.

These stations, scattered all over the country, form the most accurate basis for all surveys. With the information given by the Geodetic Survey, detail surveys for production of accurate maps may be started in many different parts of the country, with the certainty that the work of the different surveys will perfectly harmonize, with no overlapping and clashing where the different surveys meet.

Therefore, just as a house needs a foundation—just as it is economical to employ a central heating plant to serve the necessities of a number of buildings—just so do extended topographic or other surveys require a geodetic survey as a foundation to control their accuracy, and just so is a geodetic survey necessary and economical in controlling and binding together independent and sometimes previous surveys for the compilation of maps.

This latter point is well illustrated by an extract from the report of the Trigonometrical Survey of Fiji:—

> With the greater development of the country, the difficulty of reconciling the location and acreage of some of the earlier and less accurately defined properties with the results of recent contiguous surveys began to be severely felt, the fitting of new plans into old maps being sometimes impossible. This difficulty is, of course, by no means new, being experienced by almost every civilized state at some period of its development. *By all progressive governments, as soon as the resources of the state permit, it is met in the same way—by the initiation of a primary survey eventually embracing the whole area of the country.*

These remarks apply equally well to our own country. The need of a geodetic survey has long been felt in Canada. The absence of accurate maps has caused the expenditure of thousands and thousands of dollars on surveys which would never have been needed had a geodetic and a topographic survey been made long ago.

Two typical examples in this country will show, first, the difficulties encountered in compiling maps of Canada, and, second, how money could be saved by geodetic and topographic surveys.

In his report to the Department of the Interior in 1902, the chief geographer, alluding to the difficulties of compiling a new map of Canada, wrote:—

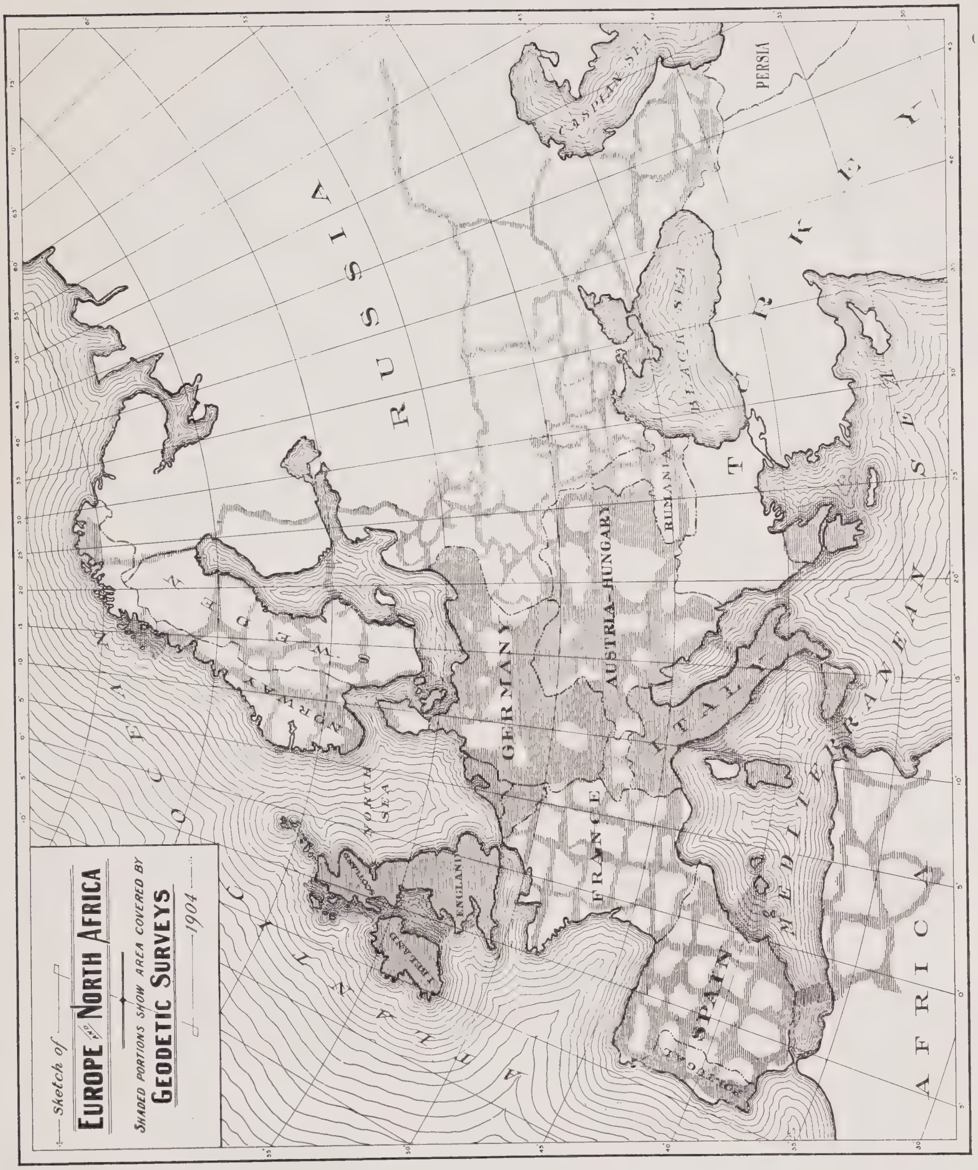
> The lack of an *accurate* topographical survey; the numerous sources from which information must be obtained; the difficulty in many cases of obtaining access to the plans of old and almost forgctten surveys; the necessity of incorporating surveys that are being made concurrently with the compilation of the map which frequently alter the work almost as soon as completed; . . . . . all tend to make the compilation of such a map a long and tedious operation.

while further on in the same report he wrote:—

> The difficulties encountered in compiling the new map of Canada emphasize the need of a good topographical map of at least the well settled portions of the Dominion. A few years ago I made a survey between two well determined points on Georgian Bay and Lake Ontario, respectively, which showed that part of Central Ontario, as shown on the best existing maps, was over two miles out in longitude and over a mile in error in latitude. Although our maps show streams, lakes, etc., even in the extreme north, much of the information on which this is based is of the vaguest kind.

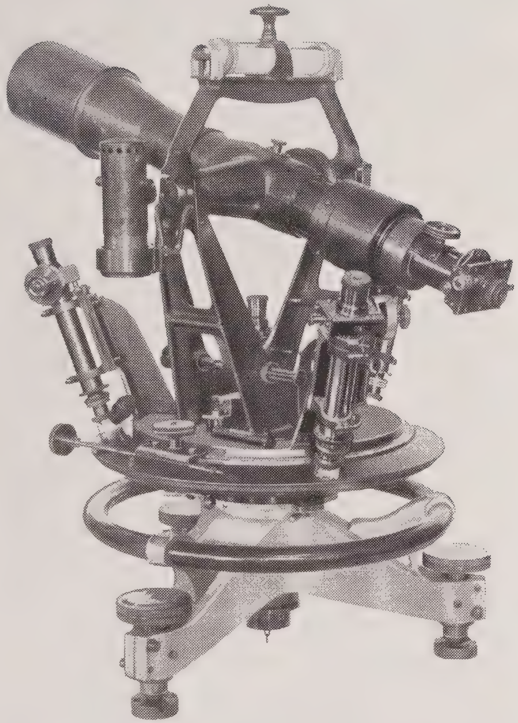
Some years ago the city of Toronto spent a large sum of money on surveys to determine the availability or otherwise of a supply of water from lake Simcoe. Had good topographical maps of that region been available, this expenditure would have been unnecessary.

It was stated above that just as a house requires a foundation, so do extended topographic or other surveys require a geodetic survey to control their accuracy. Hence a justification of topographic and hydrographic maps justifies the prosecution of a geodetic survey. One justification lies in the

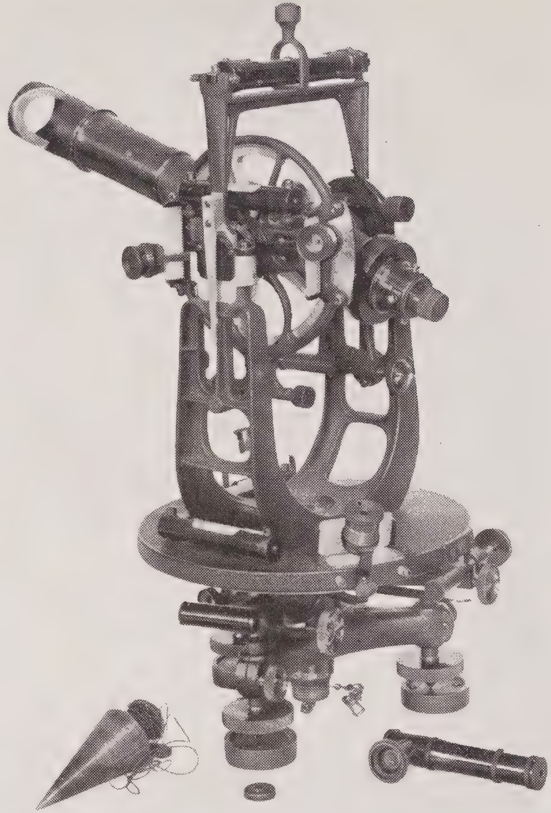


Sketch of
EUROPE AND NORTH AFRICA
SHADED PORTIONS SHOW AREA COVERED BY
GEODETIC SURVEYS
1904
RUSSIA
SWEDEN
NORWAY
NORTH SEA
ENGLAND
IRELAND
GERMANY
FRANCE
AUSTRIA-HUNGARY
RUMANIA
ITALY
SPAIN
PORTUGAL
MEDITERRANEAN SEA
AFRICA
TURKEY
PERSIA
CASPIAN SEA
BLACK SEA
ATLANTIC OCEAN


ATLANTIC OCEAN
DOMINION OF CANADA
GULF OF MEXICO
MEXICO
PACIFIC OCEAN
SKETCH SHOWING GEODETIC WORK IN THE UNITED STATES.
TRIANGULATION COMPLETED & BEGUN.
TRIANGULATION PROPOSED.
1917

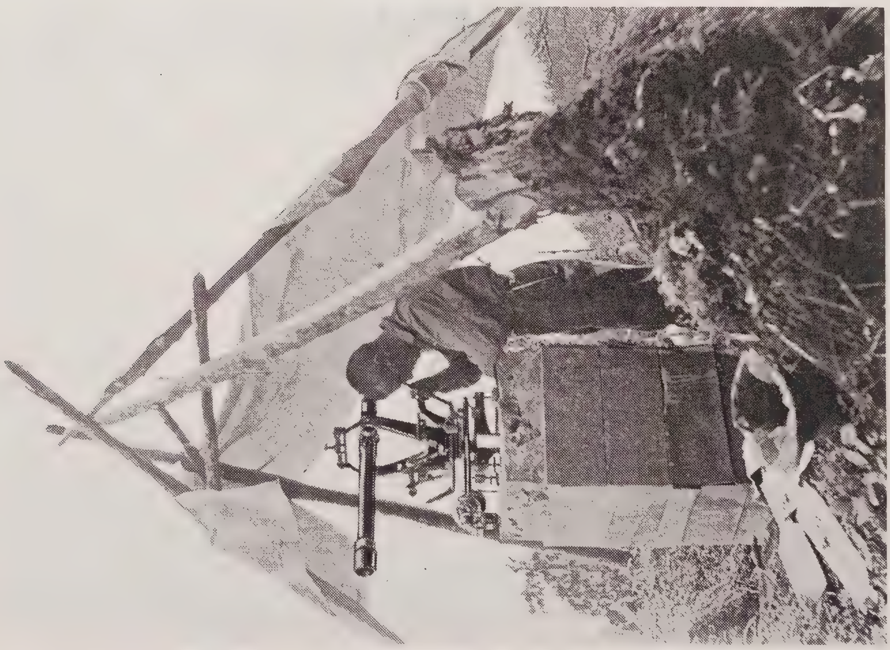


E. R. Watts 12-inch 3-Micrometer Theodolite for measuring Horizontal Angles on Primary Triangulation.



$6\frac{1}{4}$-inch Berger Repeating Transit, used for Secondary Triangulation.

Bench-mark in a culvert under the Canadian Pacific railway near Field B.C.



Ready to observe, on a mountain top in British Columbia.

procedure of other countries, while another lies in a statement of the benefits to be derived from systematic topographic and hydrographic surveys.

The two plans on pages 11 to 12 show the progress of geodetic surveys in Europe and the United States to control other surveys. These plans show typical examples, and are not to be construed as giving the whole of the world's geodetic surveys. In this connection it may be mentioned that almost as much geodetic work has been accomplished in India alone as has been completed in the United States. The large amount of geodetic work indicated on these two plans shows the great importance attached to these surveys by other countries as a basis for accurate topographic work, and gives good reason for an energetic prosecution of a geodetic survey of Canada.

A short statement of the many economic benefits resulting from topographic and hydrographic surveys might be briefly set forth to show the great need of a geodetic survey being prosecuted.

Practical.—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts and sewage plants may be laid out on them, and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoirs, routes of canals, data for equitable assessments for drainage schemes, etc., may be ascertained from these maps. The necessity of hydrographic and topographic maps of our seacoasts and great waterways is so obvious as scarcely to need mentioning.

Administrative and Military.—In all questions relating to federal or provincial administration of public works, as canals, reservations, parks, highways and postal service, and as military maps on which to plan works of offence or defence, camps, marches, etc.

Economic.—As a means of showing the location, extent and accessibility of lands, waters, forests, and valuable minerals. In this respect these maps are indispensable to provincial and federal bureaus and to owners, investors and corporations.

Statistical.—As base maps for the graphic representation of all facts relating to population, industries, products or other statistical information.

Political.—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

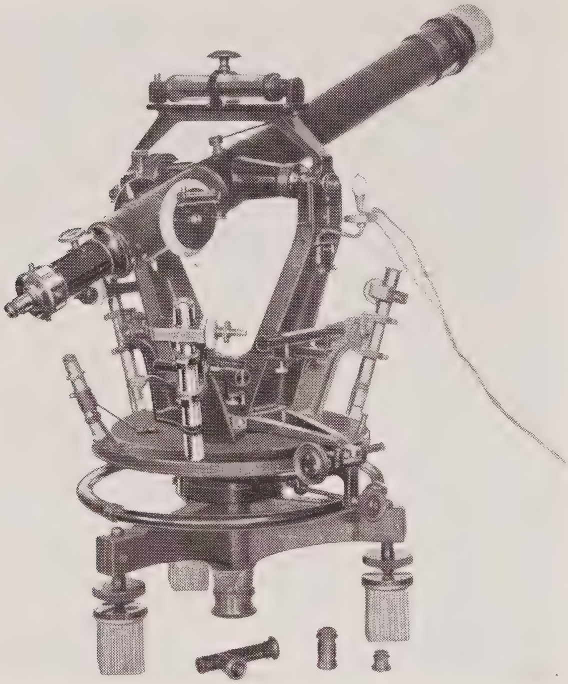
Educational.—(*a*) By promoting an exact knowledge of the country; (*b*) by serving teachers and pupils in geographical studies.

Scientific.—By providing the data for determinations of the figure, size and density of the earth.

In the above connection it is necessary to reiterate that a geodetic survey is an integral part of a topographic map, just as a foundation is part of a house, and, just as the foundation is built before the superstructure, so a geodetic survey should be made *in advance* of a topographic survey.

Another integral part of the Geodetic Survey is the precise levelling branch. Not only does the surveyor or engineer require the accurate positions of points on the earth, but he also needs points, the accurate elevations of which are known.

There are very few surveying or engineering operations which do not require differences of elevation and, in general practice, the absolute elevation



Bausch and Lomb 12-inch 3-Micrometer Theodolite, United States Coast and Geodetic Survey pattern (modified) for measuring Horizontal Angles on Primary Triangulation.

of points above some datum plane of reference is determined. The most satisfactory datum for all surveys is found to be mean sea level, as that is the datum which is obtainable at the largest number of places.

As cities, railways, etc., in the interior of the country have generally been unable to adopt mean sea level as the datum for their systems of levels, it becomes necessary that the relation between the different local datums[1] be known in

[1] Definition of the word *Datum* as applied to Geodetic work, and the formation of its plural.

In this work a triangulation is laid down on a surface of certain size and curvature, and this surface is known as Clarke's Spheroid of 1866. The adopted position in latitude and longitude of the *Initial Point* to which the triangulation is fastened and the adopted azimuth of a line emanating from this initial point define what is known as a geodetic datum (see U.S. Coast and Geodetic Report No. 30).

The adoption of such initial point and of the azimuth of a line emanating therefrom, so as to be reliable, is not easy. In the case of the North American Datum the point Meade's Ranch of latitude 39° 13′ 26″·686 and longitude 98° 32′ 30″·506 and the azimuth of such point to Waldo, were only determined after long investigation.

Thus the word *Datum*, as applied to triangulation work, conveys primarily "the adoption of the position of an initial point and of the azimuth of a line emanating therefrom," and secondarily "that the triangulation is laid down on some surface of known size and curvature."

Hence in our case the expressions "datum planes" and "datum surfaces" are not suitable, though probably convenient for other engineering work. Such expressions do not emphasize the primary characteristics of a datum (the adoption of an initial point) and in fact have a tendency to detract attention from such primary characteristics. To obtain an expression for the plural of the word "datum" that will be perfectly consistent with the definition of a geodetic datum as above stated, and that will not convey any wrong impression in relation to geodetic triangulation work, it has been proposed and approved by the International Boundary Commissioners that the plural of "Datum" for our peculiar work be "Datums."

Thus the word "datum" will have two plurals, "datums" and "data", an anglicized and a latinized plural, respectively, to express two entirely different ideas, being perfectly analogous to the word "index," which has the anglicized plural "indexes" for the peculiar meaning alphabetized lists in books and the latinized plural "indices" in reference to the exponents of algebraic numbers.

NOTE: It may similarly be seen that the same plural, "datums" could be given a further meaning as applied to level systems.

GEODETIC SURVEY OF CANADA.
PROGRESS SKETCH OF TRIANGULATION
INCLUDING WORK OF 1917
FINAL RESULTS
PRELIMINARY
STATUTE MILES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
HUDSON BAY
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
NEW BRUNSWICK
NOVA SCOTIA
NEWFOUNDLAND
PACIFIC OCEAN
ATLANTIC OCEAN

GEODETIC SURVEY OF CANADA.
PROGRESS SKETCH OF TRIANGULATION
INCLUDING WORK OF 1917
COMPLETED SURVEYS
RECONNAISSANCE
STATUTE MILES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
HUDSON BAY
ONTARIO
QUEBEC
NEW BRUNSWICK
PACIFIC OCEAN
ATLANTIC OCEAN
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE

order that all systems of levels may be of the greatest assistance to all users of this information, including those prosecuting topographic surveys.

It is evident that these relations can be obtained only by lines of precise levels connecting all parts of the country from the Atlantic to the Pacific.

Comprehensive topographic and other surveys require the elevations of points, checked at short intervals, and lines of precise levels provide these checks in satisfactory manner.

Precise levelling is, wherever possible, carried along railway tracks rather than along highways or across country, and bench-marks are established every three or four miles, and in all cities and towns through which the lines pass.

From what has been said above showing the close relation which exists between the work of the geodetic engineer—triangulation and precise levelling—and that of the topographer and hydrographer, it is evident that geodetic, topographic and hydrographic work should be prosecuted hand in hand, and that the closest co-operation of effort must exist between the divisions of geodesy, topography and hydrography in order that wasted effort may be avoided.

Organization of the Geodetic Survey of Canada

From time to time efforts were made towards starting a Geodetic Survey of Canada, and finally, in 1905, the late Dr. W. F. King, Chief Astronomer, was authorized to commence operations in the vicinity of Ottawa.

In 1909 the survey was organized by order in council, the late Dr. King being given the title of superintendent. Following Dr. King's death the present incumbent of the office of superintendent was appointed on October 4, 1917.

The staff of the Geodetic Survey has consisted, since its origin, of a small number of inside service men, many of whom possess the highest technical qualifications, together with a larger number of what have been termed "temporary employees". This system cannot be said to have worked out to the best interests of the survey or its employees, as a large percentage of these "temporary employees" are also highly trained, technical men, university graduates, etc., whose presence on the staff undoubtedly contributes largely to the standing of the survey.

It is hoped that this condition of affairs will shortly be remedied by the inclusion of the whole staff on the Inside Service, in pursuance of the undoubted spirit of the Civil Service Act, together with a standardization of the requirements for each position, thus giving recognition to the quality of the personnel of the Survey staff, and assuring to all the same privileges as those enjoyed by members of the Inside Service.

Buildings of the Geodetic Survey

Previous to 1914 the staff of the Survey was quartered partly in the Dominion Observatory, and partly in the Trafalgar building. In 1914 a building was completed for the use of the Survey staff at 980 Carling avenue, Ottawa. These commodious quarters, while sufficient for present needs, when

Geodetic Survey of Canada; Offices, 980 Carling avenue, Ottawa.

Standardizing Building of the Geodetic Survey, Ottawa.

the activities of the Survey are reduced, owing to the enlistment of many of its members for overseas service, will be found inadequate with the necessary expansion of the Survey's activities after the war.

Of vital necessity to the work of the Survey is the Standardizing building, situated about 100 yards east of the Geodetic Survey building. Here the 50-metre invar base-line tapes are standardized in order that accurate linear measurements may be made to control the lengths of the triangulation system.

Operations and Extent of Survey Activities—Triangulation, Etc.

Reconnaissance and Observing.—In 1905 the late Dr. W. F. King received the authority of the Minister of the Interior to commence primary triangulation operations in the vicinity of Ottawa, C. A. Bigger being placed in charge of the field operations. During that summer a portion of the country between the Ottawa and St. Lawrence rivers was explored for the purpose of selecting stations for the angular points of the triangulation system.

During 1906 this work was continued south and east of Ottawa, and, as the level nature of the country required the erection of towers from which to take the necessary observations, a tower-building party was organized and started in its operations.

The year 1907 saw the commencement of the observing of the horizontal angles. The reconnaissance was carried east into the Eastern Townships of Quebec and west of Ottawa.

In 1908 the reconnaissance was continued east and west in Quebec and Ontario, the observing being continued as far west as Toronto and eastward into Quebec. This year also saw a reconnaissance started in the Bay of Fundy region, New Brunswick.

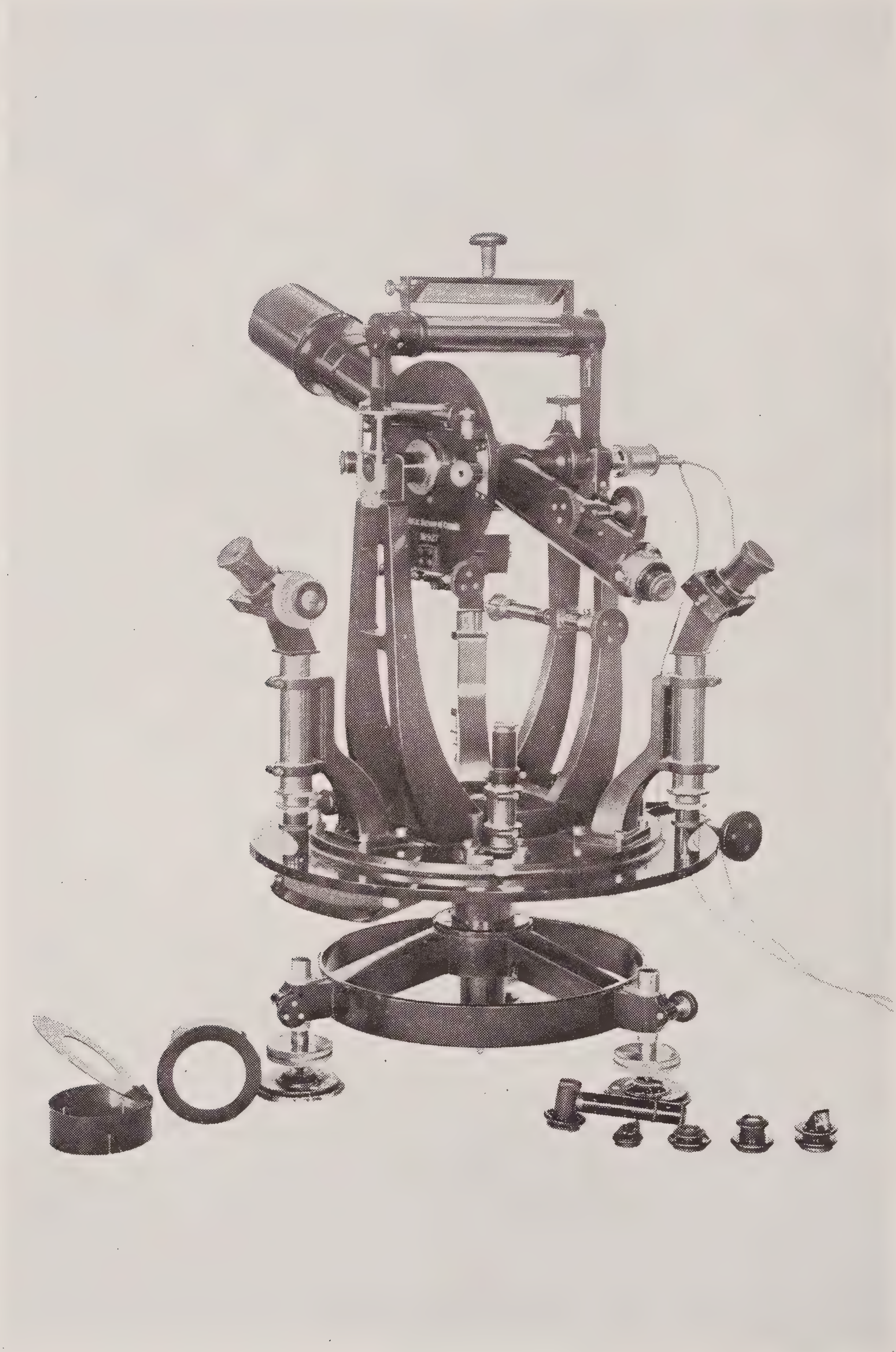
From 1909 on, reconnaissance and observing have been carried on more or less continuously in New Brunswick, Nova Scotia, Quebec and Ontario. This year also saw reconnaissance started along the British Columbia coast and in the Lake Superior district in the region from Port Arthur westward along the international boundary.

In 1910 and 1911 observing was commenced in the Port Arthur and British Columbia coast regions respectively.

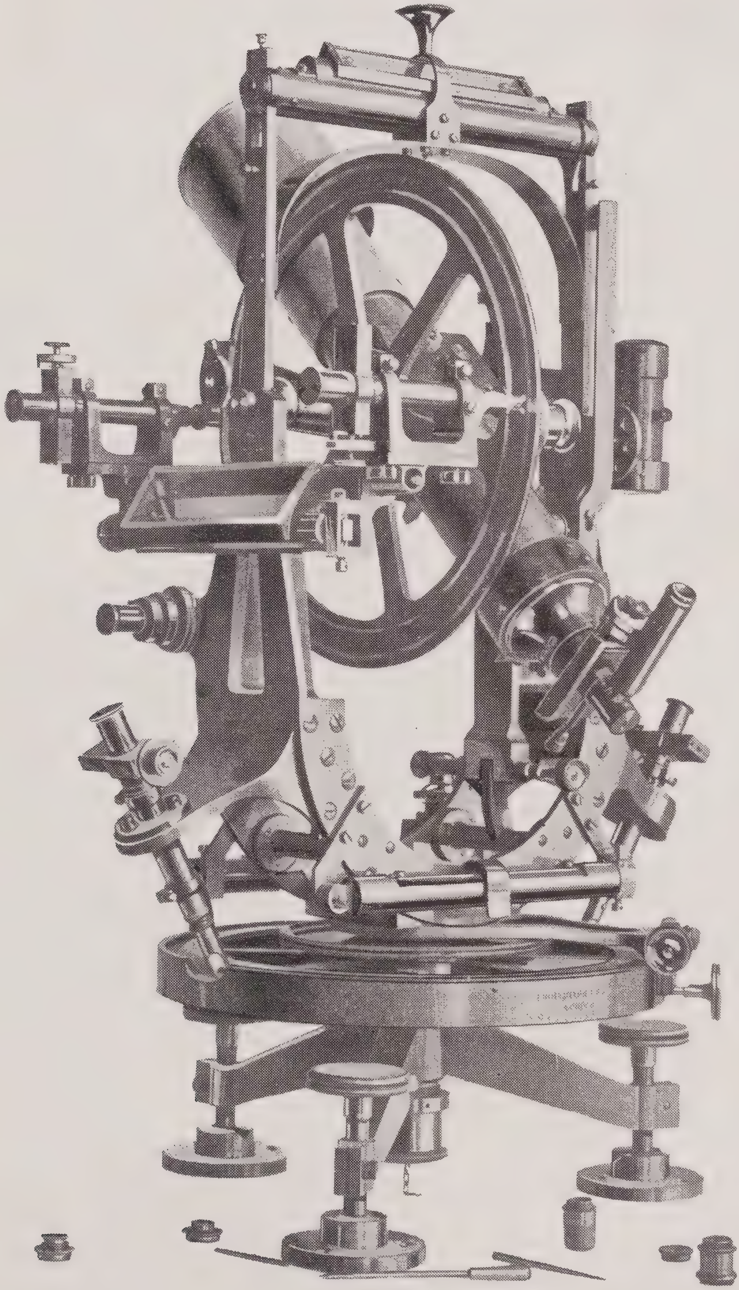
In 1910 a geodesist's office was established in charge of W. M. Tobey, D.T.S., in order that field data might be adjusted and harmonized before being published, and that geodetic methods should be studied and applied to the direction and improvement of field methods.

In 1914, reconnaissance and observing were commenced across Dixon Entrance, in order that the geographic position of the initial point of the Alaska-British Columbia boundary at cape Muzon might be determined. The undersigned, who had charge of this survey, was given the title of an assistant superintendent by the late Dr. W. F. King, C.M.G., then superintendent of the Geodetic Survey of Canada.

At the end of 1917 the necessary field data were secured which permitted the ultimate publishing of final values of the geographic positions of all located points from Rivière-du-Loup, Que., westward to Windsor, Ont.



12-inch Kern 3-Micrometer Theodolite for measuring Horizontal Angles on Primary Triangulation.



Troughton and Simms 12-inch Altitude Azimuth 2-Micrometer Transit.

Observations have already been completed over an area of about 66,000 square miles of land and water, the distribution of this amount being approximately as follows:—

	Square miles.
Maritime Provinces, largely in the vicinity of the Bay of Fundy and northward into New Brunswick, about	8,000
Quebec, on both sides of the St. Lawrence and Ottawa rivers from Rivière-du-Loup to Ottawa, and covering the whole of the Eastern Townships, about	20,000
Ontario, from Montreal to Collingwood and Windsor, and 2,700 square miles in the Port Arthur region, about	27,000
British Columbia, from Victoria and Vancouver north between Vancouver island and the mainland, together with a scheme beginning at Dixon Entrance which is to be extended southward to meet the triangulation from the south, about	11,000
Total, approximately	66,000

Reconnaissance surveys, looking to the extension of the triangulation have also been made over an additional area of about 40,000 square miles, but the observations have not yet been taken.

It will be noticed that the areas covered by the Geodetic Survey have been such as to give control to topographic and hydrographic surveys along our waterways, and in the more densely settled parts of the country. This is, of course, the direct function of the Survey, the scientific problems which may be solved from the field data secured, although very important in themselves, being of relatively secondary consequence to the economic value of Survey results. Indeed, it may be said that unless the whole civilized world had realized the great economic importance of a geodetic control for detail surveys, but a fraction of the money and energy would have been expended on geodetic surveys throughout the world that has been spent.

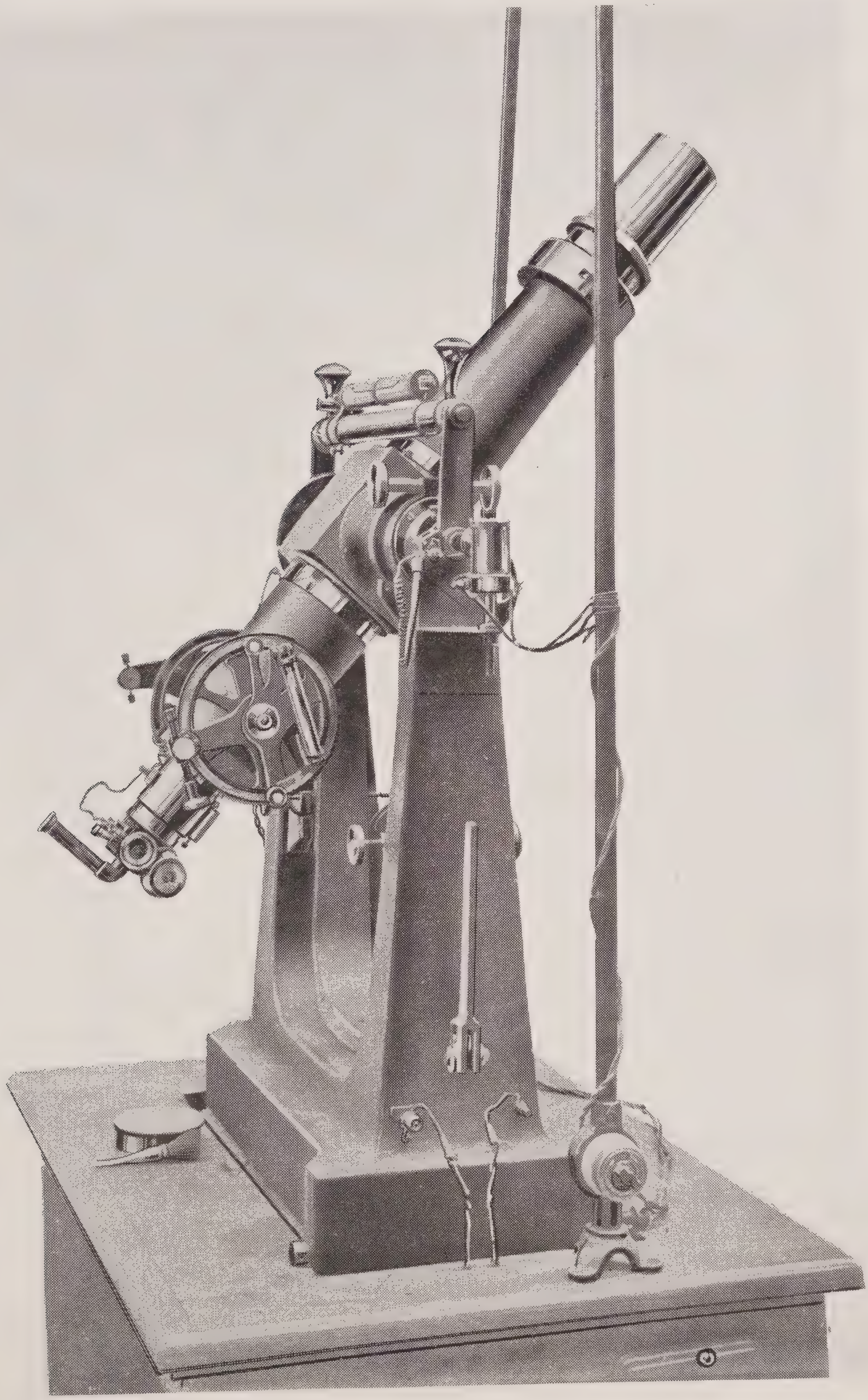
Base Lines: The distance between triangulation stations, which may be termed the scale of the triangulation, has been well controlled by seven base lines measured near Amherst, N.S., St. Jean Port Joli, Que., Coteau Junction, Que., Belleville, Ont., Collingwood, Ont., Glencoe, Ont., and near Vancouver, B.C.

These base lines have been measured with invar tapes whose lengths are standardized at necessary intervals at the Standardizing building of this Survey.

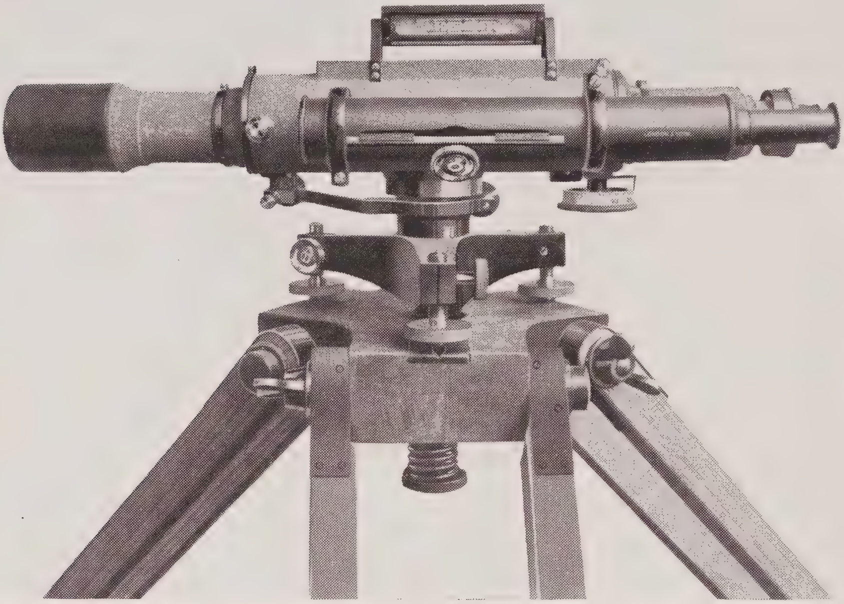
Astronomic Work: The astronomic work of the Survey consists in the establishment of Laplace stations—points at which the longitude and azimuth have been observed—roughly every 150 miles along the course of the triangulation system. These stations are established in order to correct the lateral deflection of the system—called the *twist*—from its true position.

PRECISE LEVELLING

Started in 1906, this work has advanced at the average rate of about 900 miles per year. In 1916 the Atlantic and Pacific oceans were connected by precise levelling across Canada, the error of closure by continuous lines being about one and a half feet.



Geodetic Survey of Canada Astronomical Transit, Cooke No. 2.



Precise Level of the Geodetic Survey of Canada—United States Coast and Geodetic Survey Pattern.

In order that early aid might be given those requiring field data, it was found necessary to start the work from five different bench-marks or reference points, in widely separated parts of the country, each one being connected more or less directly with mean sea level.

The different sections, with the reference points on the basis of which elevations are given are as follows:—

From Yarmouth and Halifax, N.S., to Moncton, N.B., elevations were based on the Halifax sea-level datum.

From Moncton and St. Stephen, N.B., to Rivière-du-Loup, Que., elevations were based on the St. Stephen, N.B., sea-level datum.

From Rivière-du-Loup, Que., through Quebec and Ontario to Port Arthur, Ont., the district is covered by levels run from the United States Coast and Geodetic Survey bench-mark at Rouse Point, N.Y.

From Port Arthur, Ont., to Kamloops, B.C., a bench-mark of the United States Coast and Geodetic Survey at Stephen, Minn., governed the elevations.

From Kamloops to Vancouver, B.C., elevations have been based on a mean sea-level datum at Vancouver.

The number of miles of precise levelling since the inception of the work in 1906 up to and including the 1917 operations is distributed among the provinces as follows:—

	Miles		
Ontario	3,282	Saskatchewan	928
Quebec	1,437	New Brunswick	864
British Columbia	1,385	Nova Scotia	705
Alberta	1,185	Manitoba	684
		Minnesota, U.S.A.	89

This amounts to a mileage of 10,559, and is exclusive of 491 miles of precise levelling in the Yukon in connection with the International Boundary Surveys.

The total number of standard bench-marks established since the beginning of the survey is 3,041, which number does not include those bench-marks of other organizations whose elevations have been determined by the Geodetic Survey.

No adjustment of the entire precise level net has yet been made, it being considered wiser to wait till the number of loops and checks has been increased, so that a final adjustment will not be disturbed for many years by future levelling.

In the meantime, field results with their discrepancies have been issued from year to year.

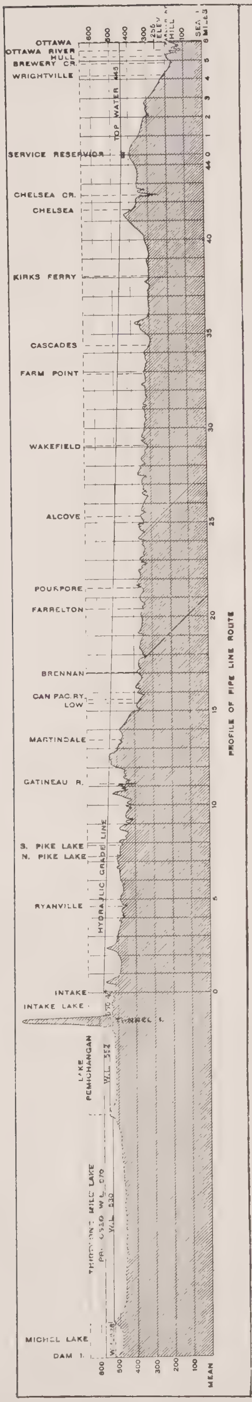
TOPOGRAPHY

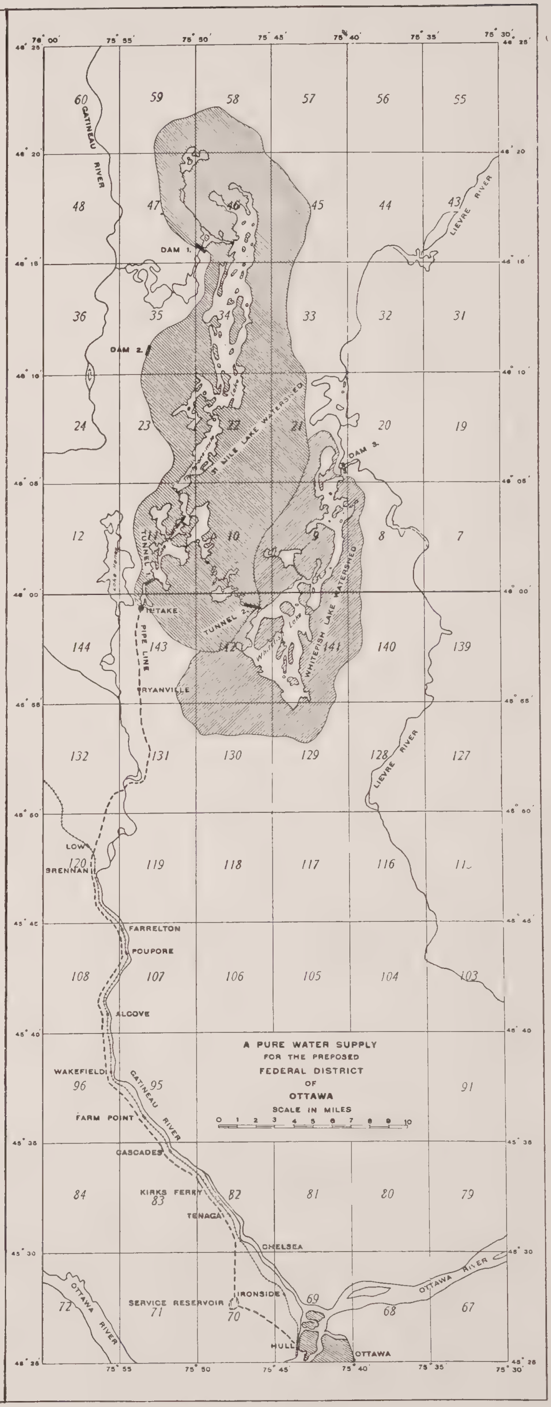
As mentioned on page 10, geodetic and topographic surveys should proceed together in order that the best economy of operation may be obtained. The Geodetic Survey of Canada, and the Canadian section of the International Boundary Surveys—on the latter of which the prosecution of triangulation and the taking of topography are extensively carried on—were both, until very recently, under the direction of the late Dr. W. F. King. An interchange of engineers between these two surveys was at times found necessary, on account of the interlocking interests of the work of each, and, with the gradual completion of the work of the Boundary Surveys, the engineers employed thereon have been gradually transferred to geodetic work. Hence the Geodetic Survey is well prepared for the prosecution of both these surveys in having a trained staff for both operations.

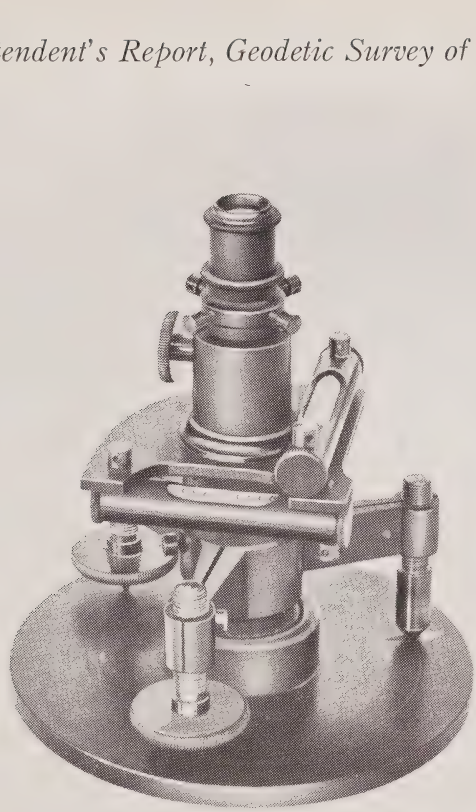
Very important topographic work was undertaken in 1913-15 by the Geodetic Survey in the prosecution of a topographic survey of the Thirtyone Mile Lake watershed and along the Gatineau river, in the interests of "A Pure Water Supply for a Proposed Federal District of Ottawa." D. H. Nelles was the officer in charge of surveys and mapping. A plan showing in brief the scope of this large work appears on page 26.

Preparations were also made for the organization of a City Mapping Division of the Geodetic Survey, to co-operate with the Civic Improvement League of Canada, but the prosecution of the required surveys was postponed until after the war.

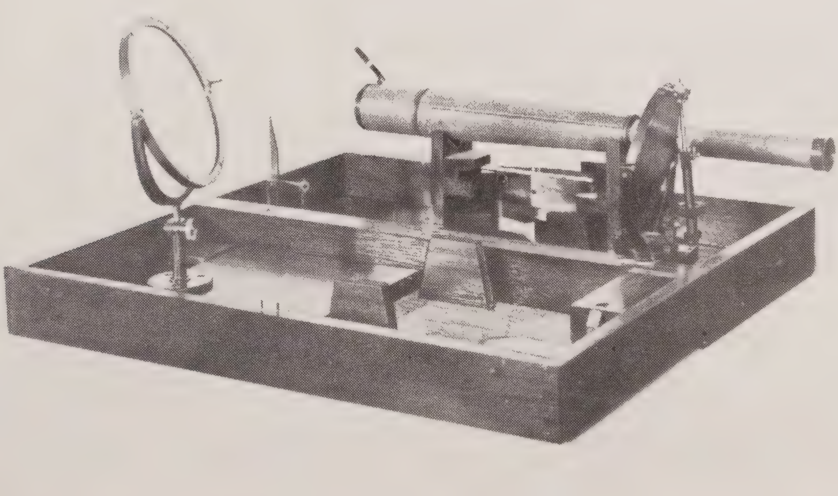
Other important topographic work was performed in 1913-15 by a member of the Geodetic Survey staff, J. L. Rannie, D.T.S., who was loaned to the International Joint Commission for the prosecution of extensive topographic surveys on the Lake of the Woods watershed, and in the preparation of the topographic maps in that district.


OTTAWA
OTTAWA RIVER
HULL
BREWERY CR.
WRIGHTVILLE
SERVICE RESERVOIR
CHELSEA CR.
CHELSEA
KIRKS FERRY
CASCADES
FARM POINT
WAKEFIELD
ALCOVE
POUPORE
FARRELTON
BRENNAN
CAN PAC.RY.
LOW
MARTINDALE
GATINEAU R.
S. PIKE LAKE
N. PIKE LAKE
RYANVILLE
INTAKE
INTAKE LAKE
TUNNEL 1.
LAKE PEMICHANGAN
THIRTY ONE MILE LAKE
MICHEL LAKE
DAM 1.
TOP WATER
HYDRAULIC GRADE LINE
PROFILE OF PIPE LINE ROUTE
MEAN SEA LEVEL

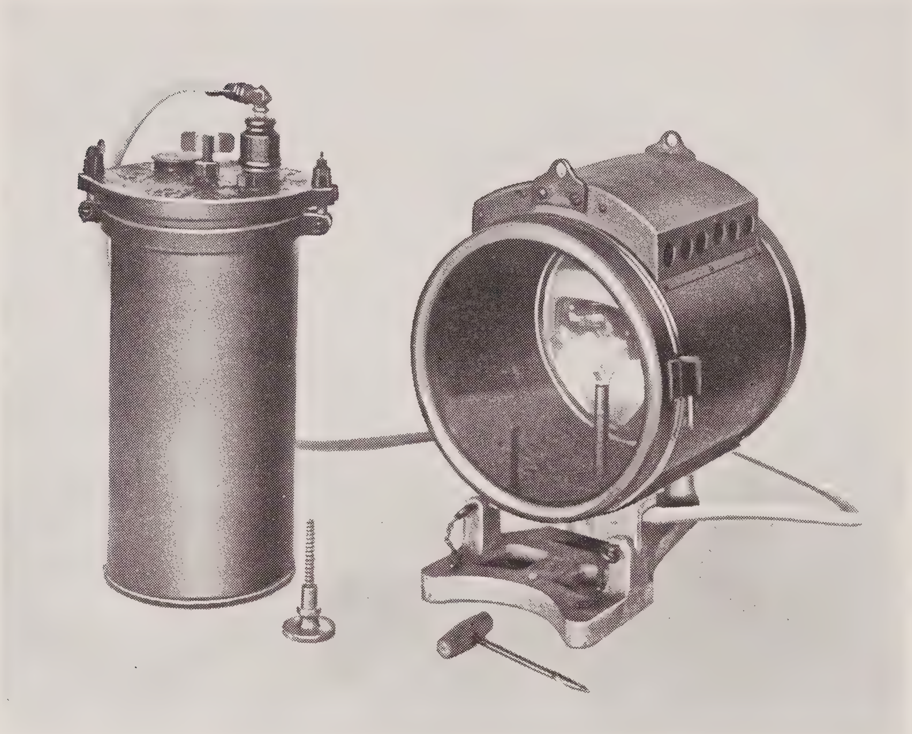

A PURE WATER SUPPLY
FOR THE PREPOSED
FEDERAL DISTRICT
OF
OTTAWA
SCALE IN MILES
GATINEAU RIVER
LIEVRE RIVER
OTTAWA RIVER
DAM 1.
DAM 2.
DAM 3.
TUNNEL 1
TUNNEL 2
INTAKE
PIPE LINE
RYANVILLE
LOW
BRENNAN
FARRELTON
POUPORE
ALCOVE
WAKEFIELD
FARM POINT
CASCADES
KIRKS FERRY
TENAGA
CHELSEA
IRONSIDE
SERVICE RESERVOIR
HULL
OTTAWA



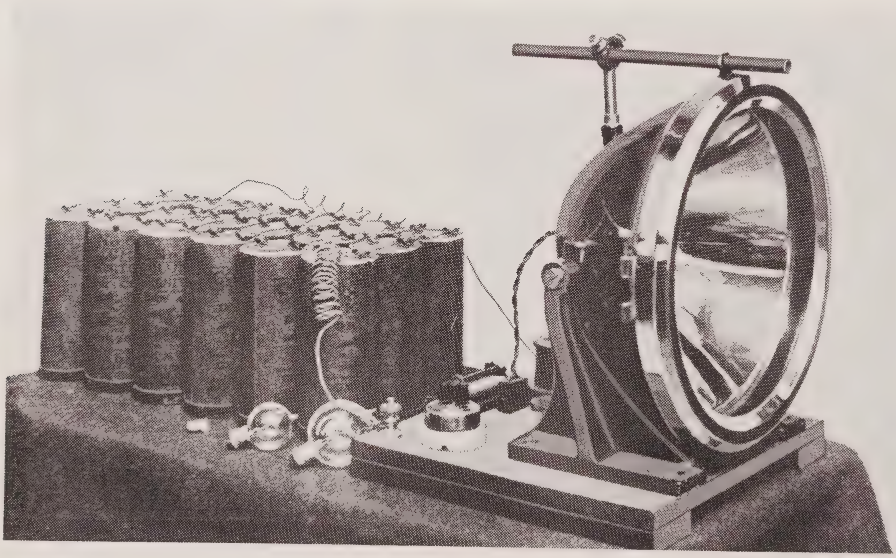
Collimator, or Look-Down instrument, used for Plumbing Down from the Top of Towers to the ground.



4-inch Cooke Heliotrope.



Acetylene Lamp with Generator, used in Night Observing on Primary Triangulation.



ELECTRIC SIGNAL LAMP.

Yields at 100 feet 250,000 candle-power with a 9-Volt, 2.5-Ampere Special Bulb, United States Coast and Geodetic Survey Pattern.

Assistance Rendered

After the outbreak of war, in the fall of 1914, the Geodetic Survey party in charge of the undersigned was glad to be able to render some assistance to the Naval Authorities in the vicinity of Prince Rupert, B.C., in establishing signal stations.

German cruisers were in the immediate vicinity of that place and, as the Geodetic Survey had parties on prominent points of outlying islands, the connecting of these points with Prince Rupert was of the greatest possible service in keeping the authorities there acquainted with what might be transpiring on Hecate strait and Dixon entrance.

Verbal thanks for services rendered were given the undersigned by Commodore Hose of H. M. C. S. "RAINBOW," and a letter was sent to the superintendent expressing the thanks of Lieut.-Col. C. W. Peck, Commanding the 68th Prince Rupert Light Infantry—now Lieut-Col. C. W. Peck, V. C., M.P.

Information Supplied

Triangulation, etc.—With the comparatively small staff and the limited appropriations at the disposal of the Geodetic Survey, it will be appreciated that the diverse operations needed for the triangulation in each section of the country, perhaps 200 miles in extent, require considerable time for final values of the latitudes and longitudes of points and the azimuths of lines to be obtained.

It is the policy of this Survey to publish only *final* data with regard to the triangulation, but many requests for information regarding the geographical position of points, where the need of such data is great, have been met by providing preliminary values in the meantime. These preliminary values may depend on only part of the field data secured, and are hence only approximate, but they may be close to the final values and may meet immediate demands.

It will be seen, however, that the time required to prepare preliminary data regarding the triangulation systems in different parts of the country, consumes part of the time of officials which might be advantageously used to hurry along final information, so that the dissemination of preliminary data regarding the triangulation systems is not encouraged.

The triangulation data of the Geodetic Survey have been used by several departments of the Government, as well as other organizations, as shown below. It is to be pointed out that the information available has been only a part of that requested, and this survey finds itself constantly behind in the matter of providing information as it is needed. Data have been supplied as follows:—

1. Militia Department—Triangulation data in Quebec and Ontario to control the accuracy of the military topographic maps.
2. Naval Department, Hydrographic Survey—Triangulation data at many points along lake Ontario and the St. Lawrence river and on the British Columbia coast to control the accuracy of hydrographic maps.
3. Interior Department, Chief Geographer's Branch—Triangulation data at many points scattered over Ontario and Quebec, for the purpose of controlling the accuracy of the compiled topographic maps of that branch.
4. Geological Survey—Data in the Ottawa and Gatineau River region for the control of Geological Survey mapping.

5. International Boundary Surveys for the control of their surveys in Quebec and New Brunswick and in Ontario west of Port Arthur.
6. Quebec Streams Commission—-Field work was undertaken and preliminary results supplied to control the accuracy of their surveys.
7. City of Toronto and Toronto Harbour Commission—Triangulation data in the vicinity of Toronto for the control of surveys in that vicinity.

Precise Levelling: In the last few years, as the work of the Precise Levelling Division of the Geodetic Survey has become better known, requests in considerable number have been received for information as to elevations of points throughout the country, and for accurately determined differences of elevation between adjoining points in certain districts.

The following is a list of requests received up to the end of the year 1917:—

Five requests from the Water Power Branch, Department of the Interior.
Four from the Irrigation Branch, Department of the Interior.
One from the Forestry Branch, Department of the Interior.
Six from the Topographical Surveys Branch, Department of the Interior.
One from the Dominion Parks Branch, Department of the Interior.
Three from the Naval Service Department.
Eleven from the Public Works Department.
Eight from the Department of Mines, Mines Branch and Geological Survey.
Five from the Militia Department.
Five from the Department of Railways and Canals.
Seven from the Provincial Government of Ontario.
Eight from the Provincial Government of Manitoba.
One from the Provincial Government of New Brunswick.
Six from the United States Government through International Boundary Commissioner.
Three from the International Joint Commission.
One from the Vancouver and District Sewerage Board.
One from the Board of Harbour Commissioners, Toronto.
One from the Board of Harbour Commissioners, Montreal.
Six from the Canadian Pacific Railway.
Two from the Grand Trunk railway.
One from the Canadian Northern railway.
One from the Algoma Central railway.
One from the Dominion Atlantic railway.
One from the Northern Pacific railway.
One from the Wabash railroad.
Nine from city and town engineers throughout Canada.
Twenty-two from private engineers, surveyors and engineering firms.

In addition to the above, full use of all our available levels has been made by Mr. James White of the Commission of Conservation in the preparation of his book of reference, " Altitudes in the Dominion of Canada " (second edition), issued in 1915.

Furthermore, attention is directed to the fact that publications have been issued from year to year for several years past giving full results of the field work, and these publications have been distributed amongst any parties known or presumed to be interested in the results in each district covered; it is undoubtedly true that many persons who otherwise would have made specific requests for information have been content to wait for such information to reach them in printed form. This applies with especial force to the several railway companies over whose lines the work has been prosecuted and who, by the terms of their agreements with the department, are to be furnished with descriptions and elevations of all bench-marks established on their property.

North American Datum

Early in the year 1913, after conferences with the United States Coast and Geodetic Survey authorities, the Superintendent of the Geodetic Survey of Canada adopted what was then known as the United States Standard Datum as the datum for Canada. This datum had been previously adopted by Mexico. It was also agreed that, as heretofore, the Clarke Spheroid of 1866 would be used by all three organizations.

On account of the international character of this adopted datum, the name was changed from the "United States Standard Datum" to the "North American Datum."

This decision to adopt the North American Datum as the datum for the results of the Geodetic Survey of Canada is such an important one, and so far-reaching in its effects, that it demands some explanation.

To define a datum as used in this sense, it may be said that after the errors of a triangulation system have been adjusted, the resulting angles and the distances between stations are used to compute the latitudes and longitudes of all the triangulation stations. These computations must be started from a station at which the latitude, longitude, and the direction to some other station are known. Also computations must be based on certain dimensions for our spheroidal-shaped earth. Then the datum for the geographical co-ordinates (latitude, longitude and azimuth) throughout that system of triangulation is the position of that system on the particular-sized earth which is assumed to be the correct one, and is defined by the co-ordinates of the station from which the computations started, and the particular spheroid used.

Thus the selection of a datum depends on astronomical observations. These astronomical results are, however, subject to errors which may be many times the errors of observation, due to the deviation of the plumb line at the points of observation, caused by the attraction of unequally distributed densities, as typified by mountains, lakes, valleys, and subsurface dense massses. The triangulation in Canada has had to be started at widely separated points from the Atlantic to the Pacific ocean, and, were a different datum, defined by astronomical observations at one point in each section, used in these different localities, the whole triangulation scheme in that locality might be shifted and twisted with this one point to which it was attached, and by which it was governed, with the result that there would be very serious overlapping or discrepancies where the different systems joined.

That these discrepancies might be serious may be seen from the fact that astronomically determined positions may be in error by as much as half a mile, due to the cause outlined above.

Thus it will be seen that it is necessary to establish a datum which is very close to the truth. The only method by which a correct datum may be determined is to have very many astronomical stations scattered over the country, and have them connected by triangulation, by which means the anomalies due to the deviation of the plumb line may be detected, and the most probable position of the initial point to which the whole triangulation is fastened, and by which the position of the triangulation is governed, be made

known. It may be easily realized that thirty or forty years might elapse before a final datum could be selected for Canada independently.

Thus was the United States Standard Datum determined after years of effort. Some 600 astronomical stations have been connected by triangulation, and the whole system of the United States Coast and Geodetic Survey has been based on this one datum. At many points the stations of the United States Coast and Geodetic Survey are available for use in building and correcting the triangulation of the Geodetic Survey of Canada; and very wisely, it is felt, the late Dr. W. F. King, then Superintendent of the Geodetic Survey of Canada, in 1913 adopted the North American Datum as the basis for the Canadian triangulation, thus saving much time and money to this country in having the question of the datum for the Geodetic Survey of Canada settled for all time, and avoiding clashes between the results of surveys in this country and between those of Canada and the United States.

Publications

From time to time, as material is presented, it is the intention of this survey to issue publications which will contain:—

(*a*) All the data made available by the operations of the survey for the use of engineers, surveyors, and surveying branches of the Government.

(*b*) Geodetic and topographic methods of both field and office work, a knowledge of which will, it is confidently expected, be of use to all engineers and surveyors prosecuting geodetic and topographic work both in this and other countries.

Only by the publication of investigations on these subjects can the work of this survey be made useful in advancing the state of theory and practice among those doing similar work.

The following are summaries of reports of the officers in charge of the various sections of the work of the survey in 1917.

Respectfully submitted,

Noel Ogilvie,

Superintendent.

GEODESIST'S OFFICE

The work of the geodesist's office, under the direction of W. M. Tobey, Assistant Superintendent and Geodesist, is summarized under the following heads:—

1. Refinement and correction of field data.
2. Location of field controls (bases and Laplace points) to control growing errors due to inaccuracies of field work.
3. Determination of precisions or probable accuracy of sides, and other external parts of the triangulation, as advisory for new field work.
4. Determination of finished data, as suitable for engineers, surveyors and general public.

The detailed reports of the above operations form a part of the function of the technical publications that are issued by the Geodetic Survey of Canada from time to time, as the material is presented.

1. Refinement and Correction of Field Data.

Even with the best of care, all field work is subject to errors. It is the duty of this office to examine these errors and see if they are kept within their proper limits. If they are too large, this office advises that certain field work be undertaken to correct these errors.

As the gauge in a munitions plant confirms or rejects the products of such factory, before they can be used, so the office, by its standards, regulates and controls the field data.

2. Location of Field Controls (Bases and Laplace Points) to Control Growing Errors Due to Inaccuracies of Field Work.

In spite of the corrections given by the office being the most probable according to theory there are still outstanding errors inherent in them which have a tendency to increase with the extent of the area covered by our triangulation.

These outstanding errors are the error of scale or dimension and that of twist or bend. The former is corrected by the location of bases, the latter by the location of Laplace points.

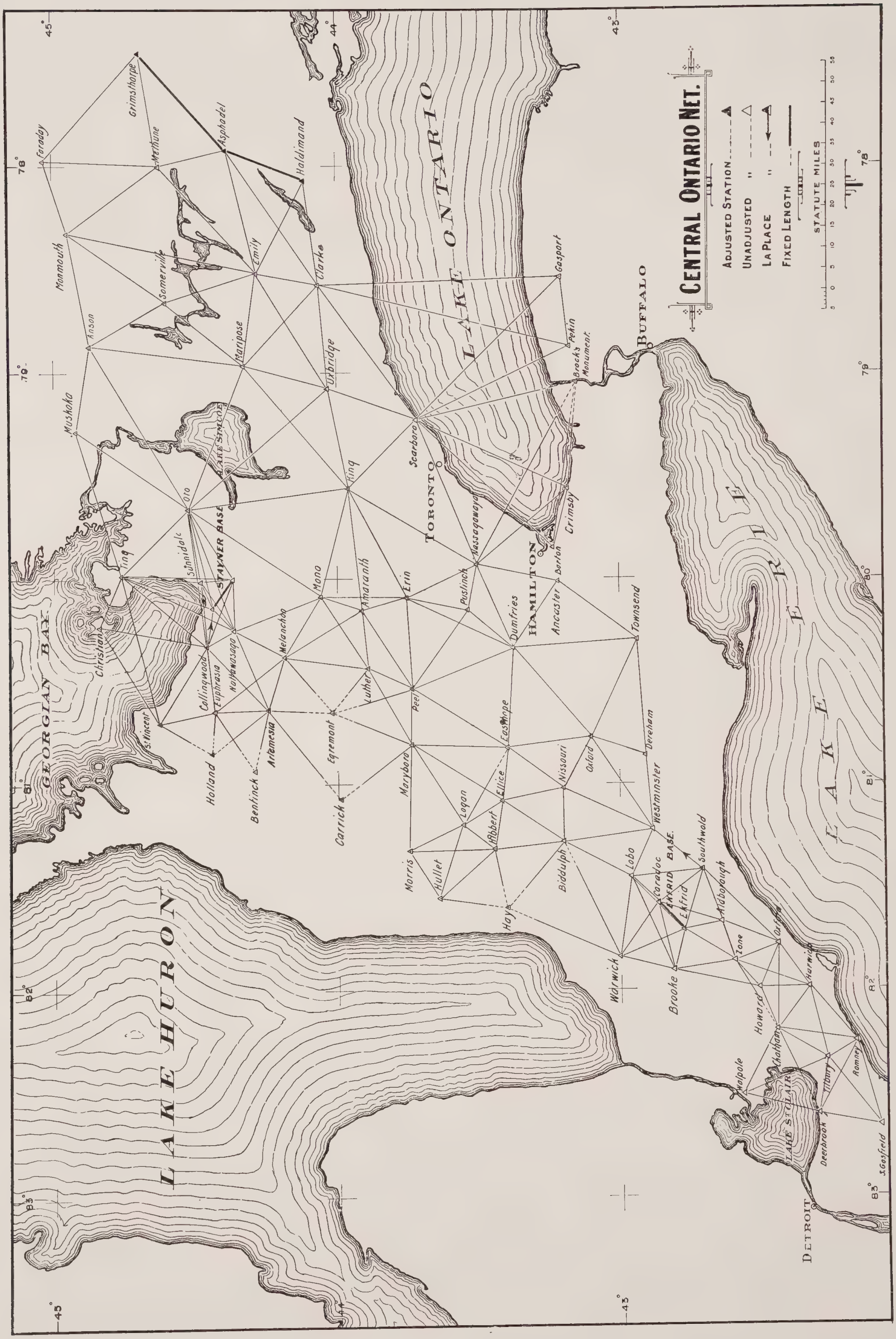
The rate of this accumulation of errors depends upon the structural strength of the triangulation system, and also on how accurately the observations have been made. Obviously the less accurate the observations, the sooner must these checks be applied.

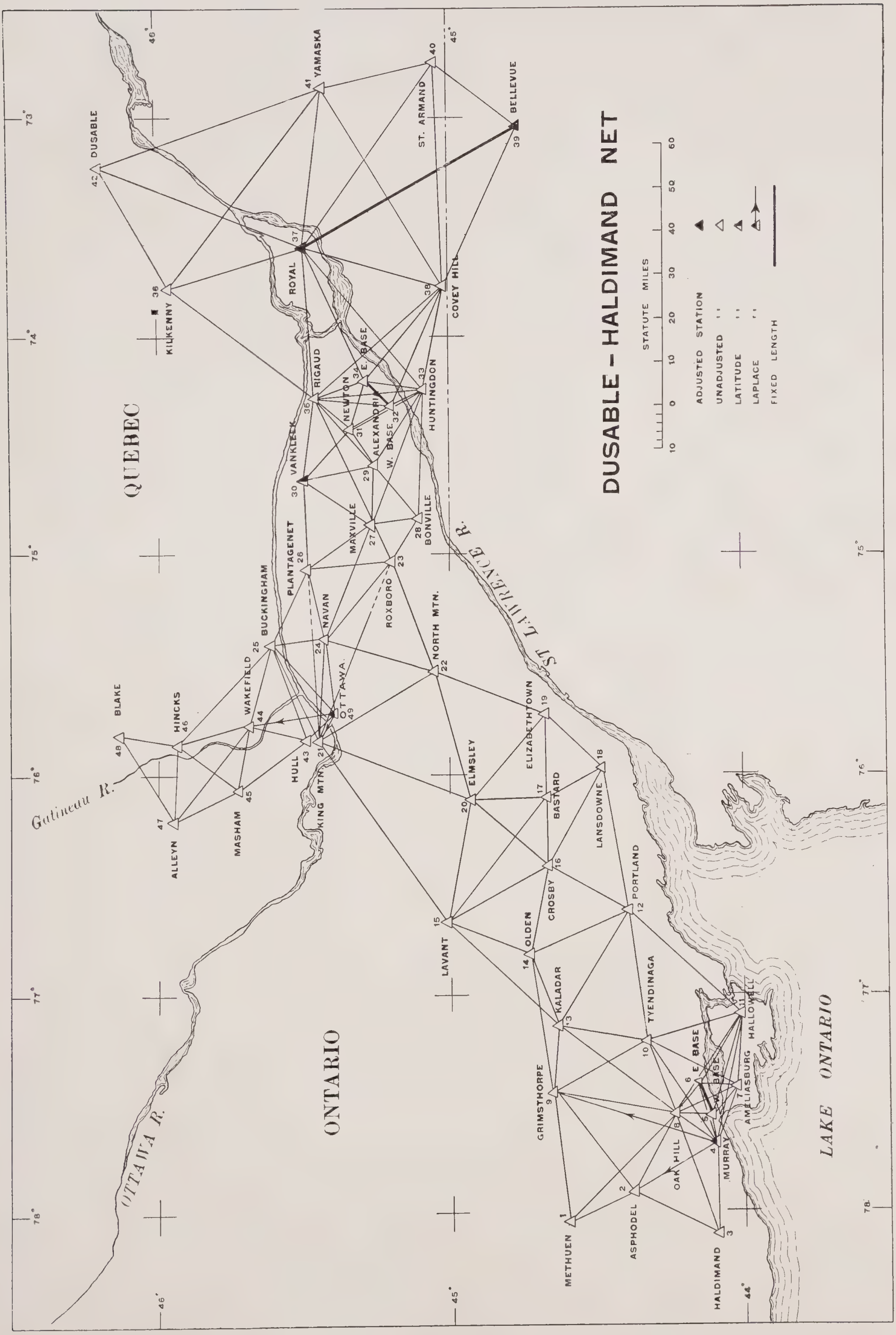
It is therefore the duty of this office so to analyze the past work as to indicate most probably the location of such bases and Laplace points.

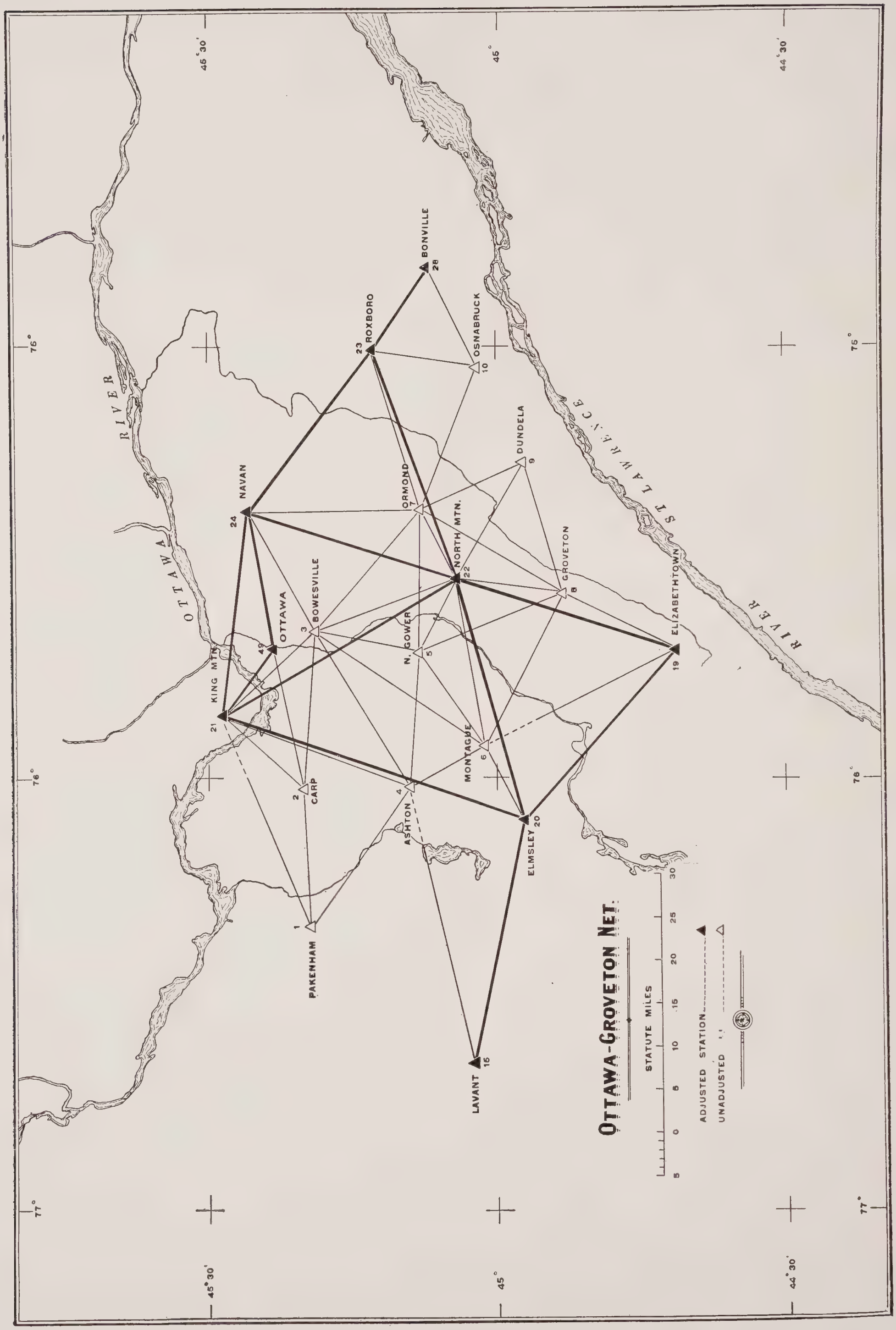
Up to the present time bases have been located near Coteau Junction, Que., near Belleville, Stayner and Ekfrid in Ontario, in L'Islet county, Quebec, in Westmorland county, New Brunswick, and near the mouth of the Fraser river, British Columbia. Also, on the suggestion of this office, Laplace points have been located at the triangulation stations, OTTAWA; MURRAY near Belleville, Ont.; COLLINGWOOD near Collingwood, Ont.; SOUTHWOLD in Western Ontario; PARKE in lower Quebec; CAPE LAZO and OLDFIELD in British Columbia. An additional Laplace point at the upper part of the Bay of Fundy triangulation is in contemplation.

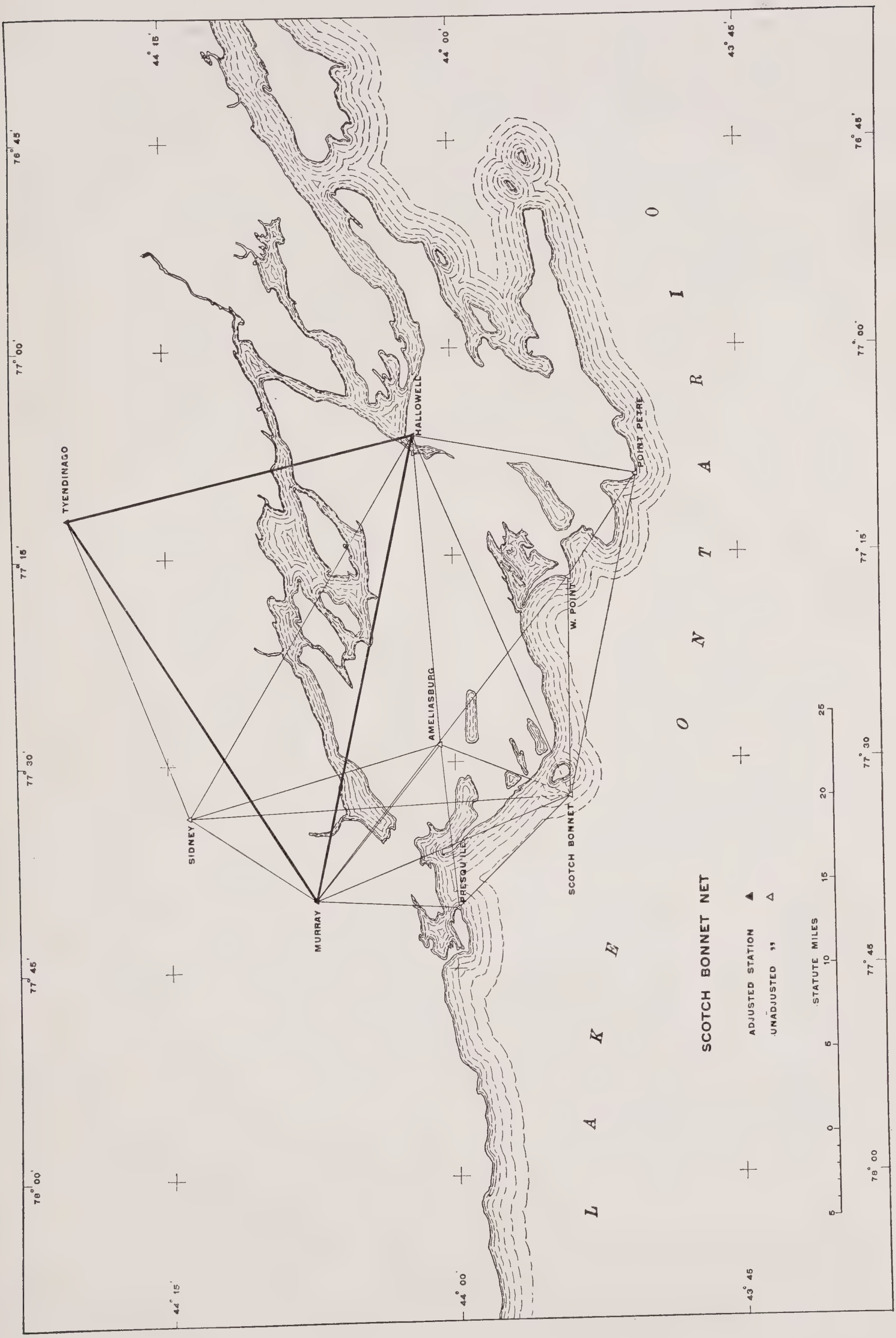
3. Determination of the Precisions or Probable Accuracy of Sides, and Other External Parts of the Triangulation as Advisory for New Field Work.

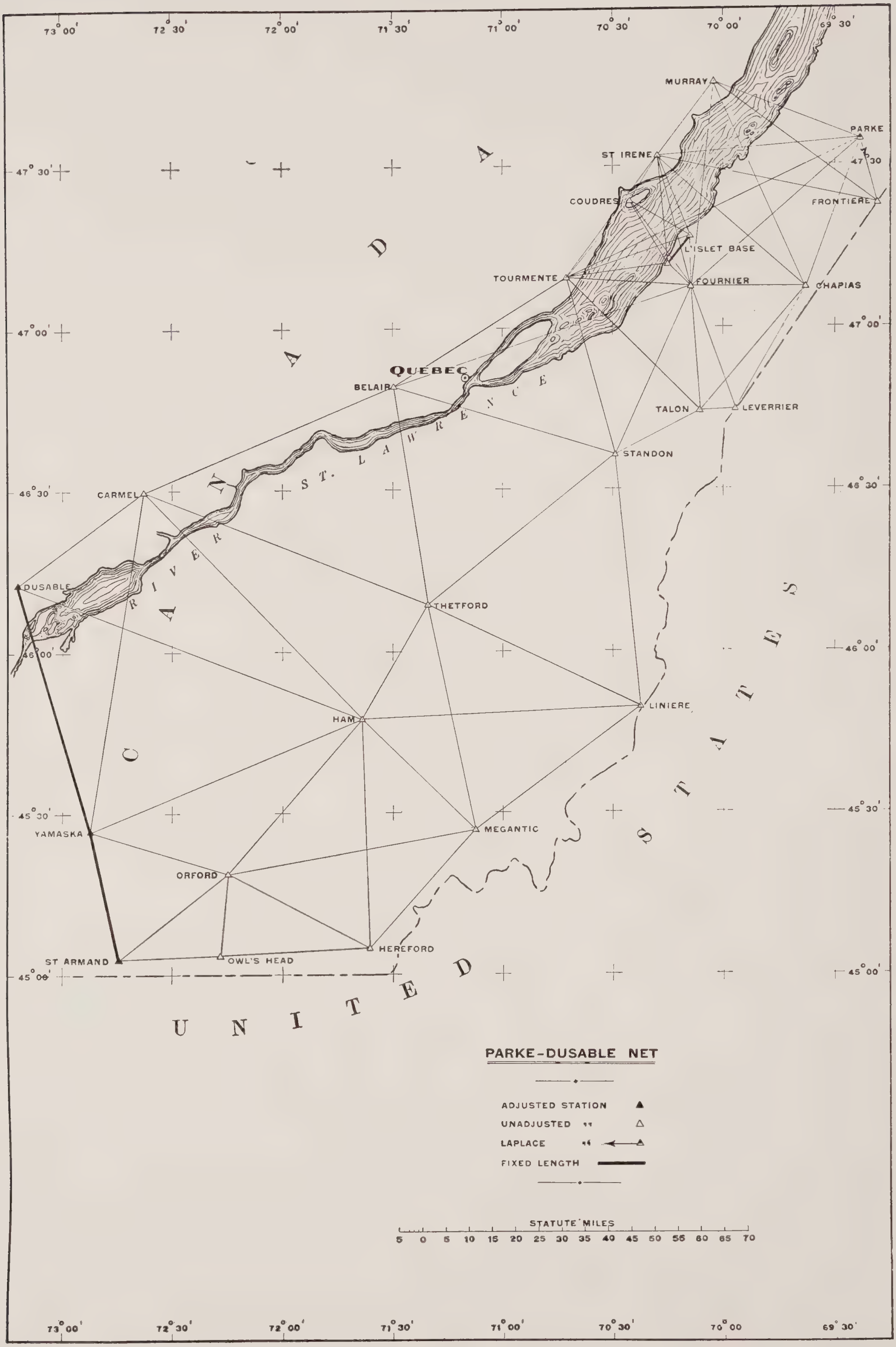
As a guide for the prosecution of new triangulations, beginning on certain sides of the old triangulation, the probable accuracy of the lengths of such sides should be known, as well as that of other parts of the old triangulation. Only by knowing the probable accuracy of these sides can the reconnaissance man have a definite idea of how far he should proceed before a base is required, and only by such knowledge can this office definitely settle the locality of the base or other controls.


CENTRAL ONTARIO NET.
ADJUSTED STATION
UNADJUSTED "
LAPLACE "
FIXED LENGTH
STATUTE MILES
LAKE ONTARIO
LAKE ERIE
LAKE HURON
GEORGIAN BAY
LAKE SIMCOE
LAKE ST. CLAIR
TORONTO
HAMILTON
BUFFALO
DETROIT
STAYNER BASE
AKFRID BASE
Faraday
Grimsthorpe
Methune
Asphodel
Haldimand
Monmouth
Somerville
Emily
Clarke
Anson
Mariposa
Uxbridge
Muskoka
Oro
King
Scarboro
Gosport
Pekin
Brock's Monument
Grimsby
Nassagaweya
Sunnidale
Mono
Amaranth
Erin
Puslinck
Barton
Ancaster
Dumfries
Townsend
Christian
Collingwood
Euphrasia
Nottawasaga
Melancthon
Luther
Peel
Egremont
Artemesia
St. Vincent
Holland
Bentinck
Carrick
Maryboro
Easthope
Ellice
Logan
Nissouri
Oxford
Dereham
Westminster
Hibbert
Morris
Hullet
Hay
Biddulph
Lobo
Caradoc
Ekfrid
Southwold
Aldborough
Warwick
Brooke
Zone
Orford
Harwich
Howard
Chatham
Walpole
Tilbury
Romney
Deerbrook
S. Gosfield


DUSABLE - HALDIMAND NET
STATUTE MILES
10 0 10 20 30 40 50 60
ADJUSTED STATION
UNADJUSTED " "
LATITUDE " "
LAPLACE " "
FIXED LENGTH
QUEBEC
ONTARIO
LAKE ONTARIO
OTTAWA R.
Gatineau R.
ST LAWRENCE R.
1 METHUEN
2 ASPHODEL
3 HALDIMAND
4 MURRAY
5 W. BASE
6 E. BASE
7 AMELIASBURG
8 OAK HILL
9 GRIMSTHORPE
10 TYENDINAGA
11 HALLOWELL
12 PORTLAND
13 KALADAR
14 OLDEN
15 LAVANT
16 CROSBY
17 BASTARD
18 LANSDOWNE
19 ELIZABETHTOWN
20 ELMSLEY
21 KING MTN.
22 NORTH MTN.
23 ROXBORO
24 NAVAN
25 BUCKINGHAM
26 PLANTAGENET
27 MAXVILLE
28 BONVILLE
29 W. BASE
30 VANKLEEK
31 NEWTON
32 ALEXANDRIA
33 HUNTINGDON
34 E. BASE
35 RIGAUD
36 KILKENNY
37 ROYAL
38 COVEY HILL
39 BELLEVUE
40 ST. ARMAND
41 YAMASKA
42 DUSABLE
43 HULL
44 WAKEFIELD
45 MASHAM
46 HINCKS
47 ALLEYN
48 BLAKE
49 OTTAWA
73° 74° 75° 76° 77° 78°
44° 45° 46°


OTTAWA-GROVETON NET.
STATUTE MILES
5 0 5 10 15 20 25 30
ADJUSTED STATION
UNADJUSTED "
OTTAWA RIVER
ST LAWRENCE RIVER
BONVILLE 28
ROXBORO 23
OSNABRUCK 10
DUNDELA 9
ORMOND 7
NAVAN 24
NORTH MTN. 22
GROVETON 8
ELIZABETHTOWN 19
BOWESVILLE 3
OTTAWA 49
N. GOWER 5
KING MTN 21
MONTAGUE 6
CARP 2
ASHTON 4
ELMSLEY 20
PAKENHAM 1
LAVANT 15
45°30'
45°
44°30'
75°
76°
77°


SCOTCH BONNET NET
ADJUSTED STATION
UNADJUSTED
STATUTE MILES
TYENDINAGO
HALLOWELL
POINT PETRE
W. POINT
AMELIASBURG
SIDNEY
MURRAY
PRESQU'ILE
SCOTCH BONNET
L A K E O N T A R I O



73° 00'
72° 30'
72° 00'
71° 30'
71° 00'
70° 30'
70° 00'
69° 30'
47° 30'
47° 00'
46° 30'
46° 00'
45° 30'
45° 00'
MURRAY
PARKE
ST IRENE
COUDRES
FRONTIERE
L'ISLET BASE
TOURMENTE
FOURNIER
CHAPIAS
QUEBEC
BELAIR
TALON
LEVERRIER
STANDON
CARMEL
DUSABLE
THETFORD
HAM
LINIERE
YAMASKA
MEGANTIC
ORFORD
HEREFORD
ST ARMAND
OWL'S HEAD
C A N A D A
ST. LAWRENCE
RIVER
UNITED STATES
PARKE-DUSABLE NET
ADJUSTED STATION
UNADJUSTED "
LAPLACE "
FIXED LENGTH
STATUTE MILES
5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

4. Determination of Finished Data, as Suitable for Engineers, Surveyors and the General Public.

The general determination of finished data, data free from clashes and incongruities, depends upon a study of the theory of errors, a theory that has been elaborated by many geodesists of the world, so as to bring about an adjustment of all the data, to give the most probable values. No adjustment will necessarily give the exact values, but only the most probable.

It is therefore necessary to do everything possible to *increase* the probability of the accuracy of such values. This is done by welding or moulding as much of the field data into one and the same net as is compatible with human ability aided by all devices possible to alleviate the burden.

While adjustments could be made of smaller nets, thus entailing far less work and quicker results, yet it is felt that such a process for a Geodetic Survey, which is primarily to control other surveys, would lessen the reliance that could be placed on these results, and so defeat the great aim of our work. To increase the probability of the accuracy of our Geodetic Survey results so that they will be a true aid to other surveys, demands an adjustment of as large nets as possible, with all the data, in one simultaneous operation.

To this end the net Dusable-Haldimand, see p. 35 for illustration, has been adjusted as a whole, thus giving:—

(*a*) Final values of latitudes and longitudes of different points, freed as far as possible from the influence of errors of scale and twist.

These will, it is hoped, be more and more used by different surveyors and engineers and other departments, as bases for secondary, tertiary and topographical surveys.

(*b*) Precision of certain parts of the net, thus giving not only a comparison of the resulting strength and weakness of such parts, but affording a determination of the reliance that can be placed on them by future users of such points.

This is especially of necessity for the reconnaissance man in the enlarging of new field work from this net as a basis, and to the user of these results as a basis for other surveys.

(*c*) The influence not only of the bases but of the Laplace points at Murray and Ottawa upon *all* the structure of the net, and showing how much the twist correction of the Laplace points preponderated over the scale correction of the bases.

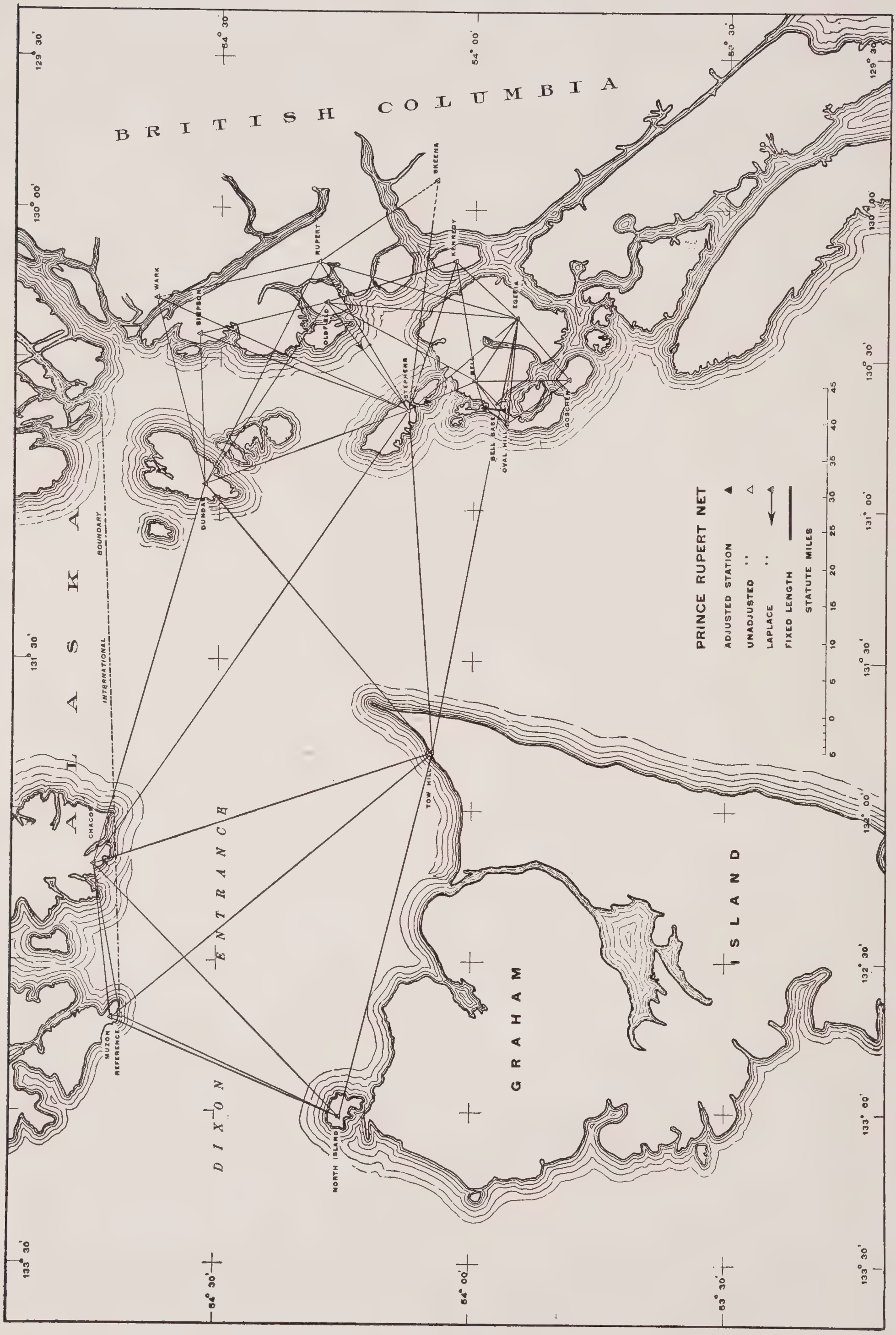
In the same region as the Dusable-Haldimand net, and depending on it for certain fixed positions, are the Ottawa-Groveton and the Scotch Bonnet nets. (See pages 36 and 37 for diagrams.) The former embraces a number of primary points between the Ottawa and St. Lawrence rivers not included in the solution of the Dusable-Haldimand net, while the latter takes in practically the whole of Prince Edward county.

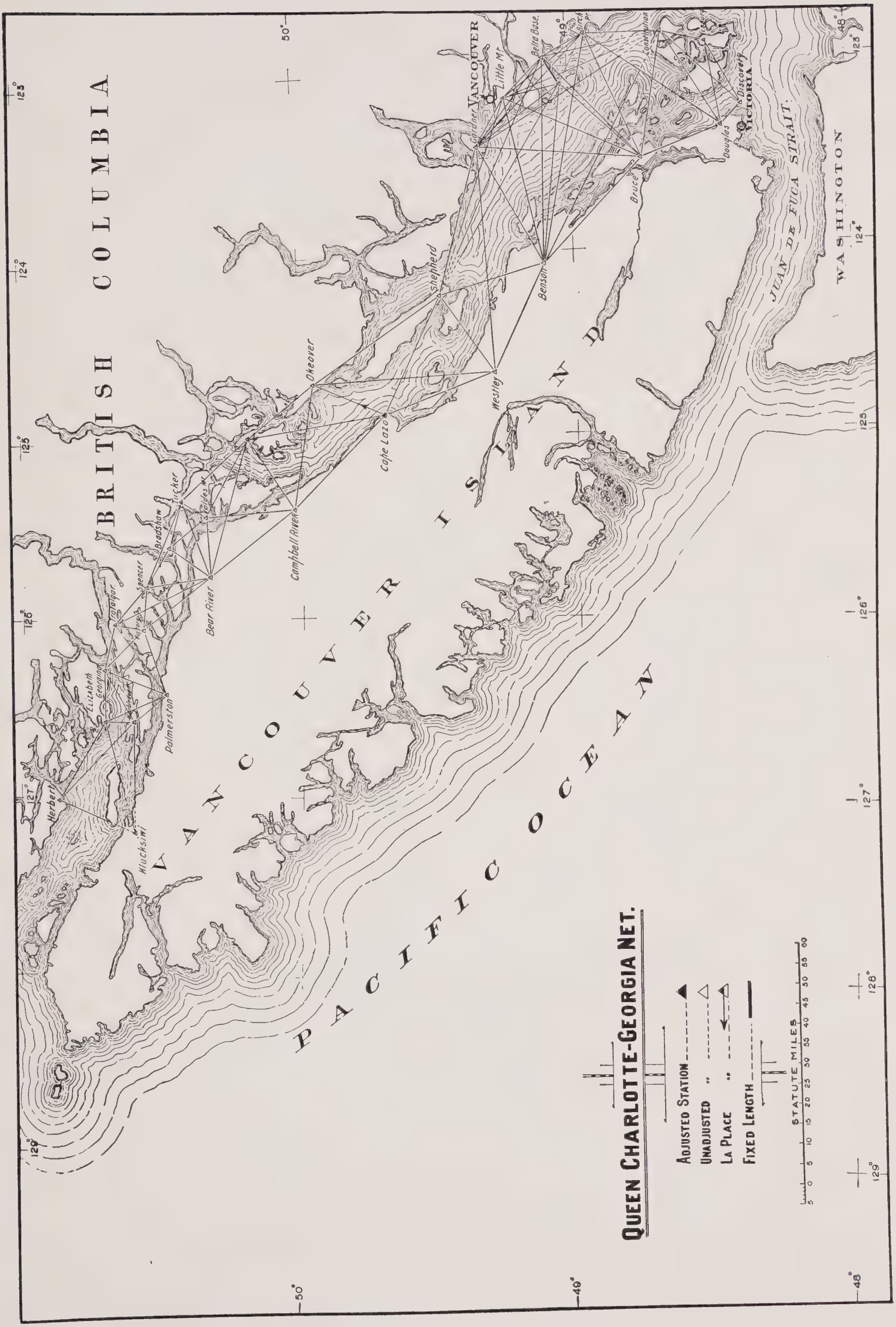
The secondary points, such as church spires, depending upon these nets have all been adjusted in their positions, and are therefore ready for use.

Nets embracing severally

- The province of Quebec,
- Bay of Fundy region,
- Western Ontario,
- Port Arthur region,
- British Columbia coast,

have all been adjusted in a preliminary sense and will, when other necessary data have been obtained, be transformed into a final stage.


BRITISH COLUMBIA
ALASKA
INTERNATIONAL BOUNDARY
DIXON ENTRANCE
GRAHAM ISLAND
WARK
SIMPSON
RUPERT
SKEENA
KENNEDY
OLDFIELD
EGERIA
STEPHENS
BELL
BELL BASE
OVAL HILL
DUNDAS
CHACON
MUZON
REFERENCE
NORTH ISLAND
TOW HILL
PRINCE RUPERT NET
ADJUSTED STATION
UNADJUSTED "
LAPLACE "
FIXED LENGTH
STATUTE MILES
5 0 5 10 15 20 25 30 35 40 45
129° 30'
130° 00'
130° 30'
131° 00'
131° 30'
132° 00'
132° 30'
133° 00'
133° 30'
54° 30'
54° 00'
53° 30'


QUEEN CHARLOTTE-GEORGIA NET.
ADJUSTED STATION
UNADJUSTED "
LA PLACE "
FIXED LENGTH
STATUTE MILES
BRITISH COLUMBIA
VANCOUVER ISLAND
PACIFIC OCEAN
JUAN DE FUCA STRAIT
WASHINGTON
VANCOUVER
VICTORIA
Gardner
Little Mt
Belta Base
Birch Pt
Constitution
Discovery
Douglas
Bruce
Benson
Shepherd
Westley
Okeover
Cape Lazo
Campbell River
Tucker
Bradshaw
Spencer
Bear River
Elizabeth
Georgina
Palmerston
Herbert
Hucksinii
50°
49°
48°
123°
124°
125°
126°
127°
128°
129°

PROGRESS OF TRIANGULATION IN BRITISH COLUMBIA.

OTTAWA, December 1, 1917.

W. H. MacTavish, Geodetic Engineer, makes the following report on the progress of the triangulation on the British Columbia coast.

The primary triangulation along the British Columbia coast was continued in 1917 in the vicinity of Prince Rupert, the angles from four primary stations being observed. Three of these stations are on Porcher island, and the remaining one is on Goschen island, as shown on the sketch on page 40. As the lines from these stations are very short, no difficulty was experienced in the reading of the angles. The angle measurements were made at night—the ordinary acetylene lamps being used to point on.

DIFFICULT OBSERVING

On the completion of the short lines, preparations were made to connect the islands adjacent to Prince Rupert with the Queen Charlotte islands. Accordingly, light-keepers were stationed at TOW HILL on the northerly end of Graham island, and at station CUM on Louise island about 80 miles south of TOW HILL, the station on Stephens island being occupied. The distance from this station to TOW HILL is approximately 50 miles, while the distance to the CUM station is about 100 miles. On account of this long line the light-keepers on CUM were given two lamps which they placed on the pier, one above the other.

On ten nights, between August 8 and September 7, attempts were made to read on the Queen Charlotte Island signals, but on only one night was the CUM light visible, and then only when there was no illumination in the field of the telescope. The TOW HILL light was visible on several nights. On account of the early termination in the season of the observing, the attempt to connect by angular measurements the stations CUM and TOW HILL with Stephens had to be abandoned.

BASE LINE SITE SELECTED

As soon as the observing was abandoned for the season, the services of about half the number of men composing the party were dispensed with, the remainder continuing work in making a stadia survey of a proposed base line sight on Porcher island. As any one knows, who is familiar with the nature of the country along the British Columbia coast, the task of selecting a suitable base line is not by any means an easy one. The one over which levels were run in the latter part of September is about $4\frac{1}{3}$ miles in length. As the profile of this base line, which has since been plotted, shows, the ground is very uneven, but with some preparation by way of clearing, etc., the base may be accurately measured. Towers about 35 feet in height will need to be erected at both ends of the base in order to make the ends intervisible. The expansion from the base is good.

Recommendations

As the proposed triangulation scheme along the British Columbia coast involves fourteen lines varying in length between 85 and 140 miles, and on account of the fact that no success was met with last summer in the attempt to read on two lights used as one signal at slightly less than 100 miles, I take the liberty of emphasizing your suggestion of a couple of years ago that some light of greater candle-power than the acetylene light which is ordinarily used on primary work be adopted for these long lines. Probably the electric signal lamp of 250,000 candle-power recently invented by a member of the United States Coast and Geodetic Survey might be satisfactory. The candle-power of the ordinary acetylene lamp being only 1,500, the advantage of the electric lamp is readily apparent. The electric lamp would be considerably more expensive than the acetylene lamp, although since its adoption by the United States Navy, Forest Service, Coast Guard and Aeronautic Service, it might be procured at a reasonable figure. Even though it were several times as expensive as our own acetylene lamp, it would still be economy to use it on long lines such as some of those on the British Columbia coast, since so much time would be lost on the long lines were the acetylene lamps used. Unless the atmosphere is exceptionally clear, 50 miles is about the limit at which observations can be satisfactorily made on the acetylene light in that country. If then we desire a satisfactory signal at 100 miles, theoretically we should employ four lamps, while at 140 miles we would need about eight lamps. It would almost be out of the question for a light-keeper to attend to that number of lamps. The merits of the electric lamp are, I think, worth while investigating.

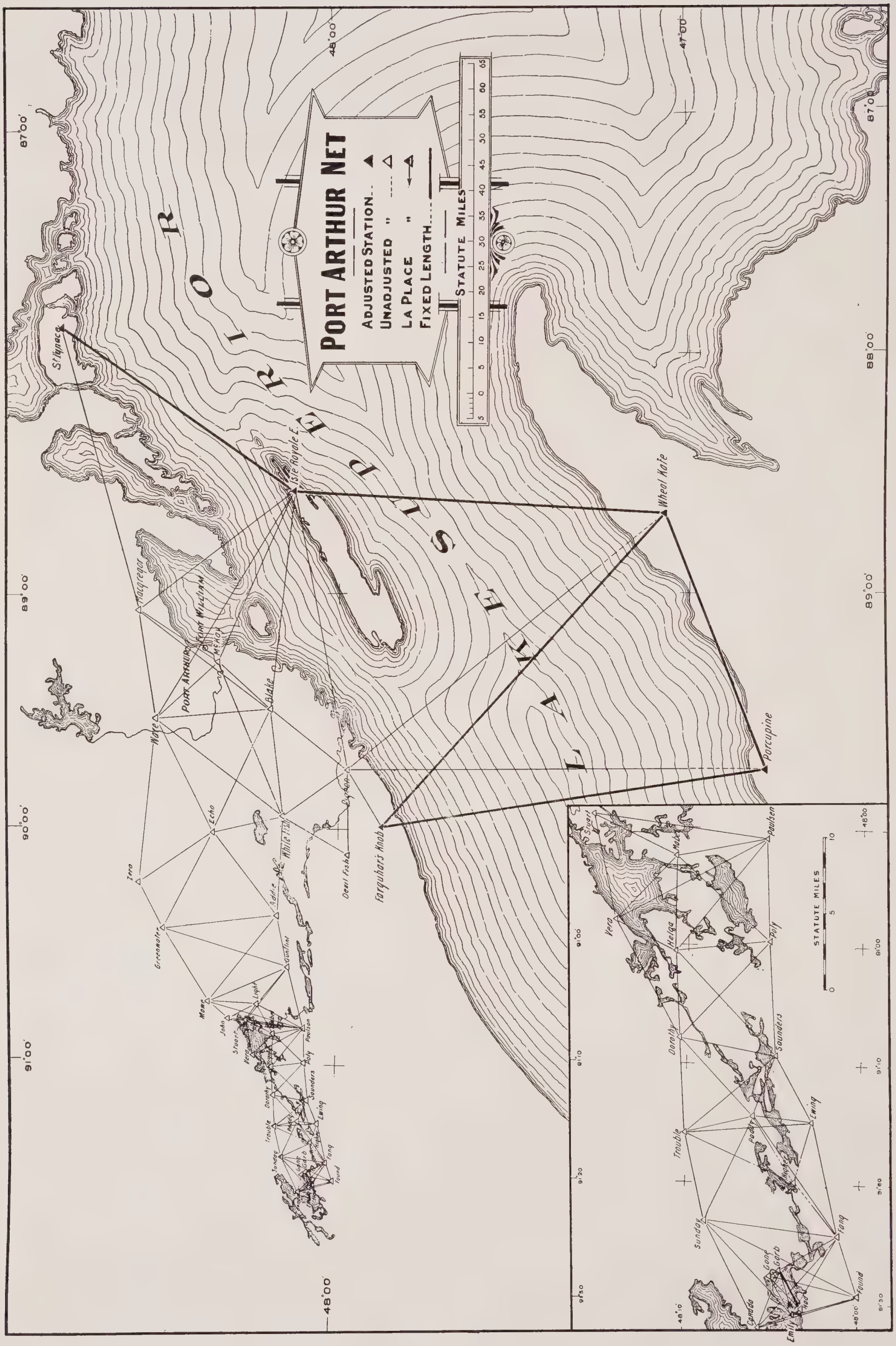
PROGRESS OF PRIMARY TRIANGULATION WEST OF PORT ARTHUR.

Ottawa, December 1, 1917.

Lindsay O. Brown, Geodetic Engineer, reports as follows on the work during the season of 1917 in the country west of Port Arthur.

Primary Triangulation

The primary triangulation in the locality between Port Arthur and Fort Frances was continued westward from the stations Ewing and Sunday. The location of the various stations of the Geodetic Survey of Canada had already been chosen. This had been done as per instructions, with the object always in view of so locating the stations that they might act as a control for the International Boundary Survey. There remained to be done the setting of the survey signals and the instrument work at various stations. Eleven signals were renewed, and five stations were occupied by an observer. Several of these stations were also used by the United States party on the International Boundary Survey. The scheme was connected with the point Emily, which is


PORT ARTHUR NET
ADJUSTED STATION
UNADJUSTED "
LA PLACE "
FIXED LENGTH
STATUTE MILES
LAKE SUPERIOR
St Ignace
Isle Royale E.
Wheal Kate
Porcupine
Farquhar's Knob
Macgregor
FORT WILLIAM
PORT ARTHUR
Kate
Blake
Echo
Zero
Greenwater
White Fish
Devil Fish
Mone
Light
John
Stuart
Vera
Dorothy
Trouble
Sunday
Paulsen
Poly
Saunders
Ewing
Fang
Found
Helga
Canada
Emily
STATUTE MILES
87°00'
88°00'
89°00'
90°00'
91°00'
48°00'
47°00'

a Laplace station (longitude and azimuth observed). The International Boundary base line on Basswood lake was incorporated in the scheme. Thus the work between St. Ignace, 70 miles east of Port Arthur, and Basswood lake now constitutes a complete system with checks at each end.

Boundary Marks Located

Acting on instructions from your office, certain marks on the boundary between Rainy River and Thunder Bay districts were established for the use of the Ontario Forestry Service. As the old boundary marks had been lost, it was necessary to retrace the southern six miles of this line to lake Seiganagaw. Copper bolts were placed where this boundary line crossed islands in lake Sagonagons and on the shore of lake Seiganagaw.

Land Survey Posts in Quebec Located

The next work undertaken was southeast of the city of Quebec in the counties of Bellechasse and Wolfe. The longitude and latitude of certain provincial survey posts in these counties were established by connecting two of them with stations of the Geodetic Survey of Canada. This work was undetaken for the use of the Chief Geographer, and is to be used for correcting the provincial maps of this district.

PROGRESS OF PRIMARY TRIANGULATION, ONTARIO AND QUEBEC

Ottawa, December 1, 1917.

J. L. Rannie, a supervisor of Triangulation and Topography, makes the following report on the work accomplished during the field season of 1917 in Ontario and Quebec.

During the past season the party in charge of the undersigned was occupied in observing horizontal angles to obtain the connection of two base lines in Ontario and Quebec, respectively, on to the main scheme of triangulation, together with some reconnaissance for projecting the existing scheme into new territory on the lower St. Lawrence river.

The party left for the field on May 5 last for the Georgian Bay region of the province of Ontario, and was occupied in that region till August 15 in connection with the Stayner base net observations. The party was then moved to the lower St. Lawrence River district in the province of Quebec, and from August 25 till September 29 were engaged on horizontal observations in connection with the L'Islet base net. For the next month reconnaissance, station preparation and several other matters occupied our attention in the lower St. Lawrence River district, the party being disbanded, owing to the lateness of the season, on October 29, before the reconnaissance was definitely completed.

Party

The observing party consisted of an observer, recorder, cook, field assistant —who acted as light-keeper when not otherwise engaged—and two light-keepers. Additional light-keepers, assistant light-keepers and labourers were secured locally as required, the amount of help hired locally during the observing period, outside of the permanent organization, averaging fifty days for one man per month. During the month of October the original number of six men constituted the party.

In Ontario, light-keepers occupied their stations alone, but in Quebec the rough and inaccessible nature of the country at some of the stations required an assistant light-keeper to be stationed with each light-keeper.

Scope of the Season's Work and Progress

Stayner Base Net.—In this net observations of horizontal angles were made at seven stations, three of which had been occupied before in connection with observations on the main scheme of triangulation.

When the observations were completed the towers at the two ends of the base, which were on the right of way of the Grand Trunk railway near Stayner, Ont., were taken down and the lumber sold at the most advantageous terms obtainable.

Other Stations.—Four other stations in this vicinity were occupied from July 29 to August 15 in order that observations might be secured on several towers which had been erected a number of years ago, so as to avoid any reconstruction of these old towers if, for any reason, future work in this section were delayed.

A plan of the stations occupied in the above section is shown on page 34.

To complete the observing at these eleven stations in Georgian Bay district took from May 7 to August 13, an average rate of nine days per station.

L'Islet Base Net.—The work on this net comprised observations of horizontal angles at six stations, of which three stations had previously been occupied in connection with the main scheme observations.

Also, another station of the main scheme in this vicinity, Frontier, which had not been occupied previously, was occupied after the observations on the base net were completed.

The weather during the progress of the work in this section was most favourable for observing, and the progress was consequently rapid, in spite of the delays in moving camp necessitated by the roughness of the country and inaccessibility of some of the stations. The observing in this section at these seven stations occupied the time of the party from August 25 till September 29, an average rate of 5·1 days per station.

Reconnaissance.—This work had for its object the extension of the present scheme of triangulation, from the northeastern end, down the St. Lawrence river, with a view also to providing points from which a scheme of triangulation could be projected up the Saguenay river when desired. It was also held

in mind that from the same vicinity—the present northeastern end of the net—triangulation would be ultimately projected to connect on to the New Brunswick net.

Secondary points were also to be selected with a view to ease of cutting in lighthouses, etc., on the St. Lawrence river and church spires or other tertiary marks along the banks.

The country up the Saguenay river as far as Chicoutimi, some 60 miles up from the north, is very rough and rocky, quite unsettled and unprovided with roads. Hence the following broad principle for guidance in reconnaissance for triangulation up the Saguenay is thought to best serve the purpose: Select the main scheme with long sides—about 30 miles—so as to have as few stations as possible far back from the river, and establish secondary points close to the river, every 10 miles or so, or wherever desired.

Four secondary points and four primary points were selected and prepared for observing.

PROGRESS OF RECONNAISSANCE AND OBSERVING IN NEW BRUNSWICK.

OTTAWA, January 22, 1918.

A. J. Brabazon, Geodetic Engineer, submits the following report on the progress made with the Geodetic Survey in western part of the province of New Brunswick during the past season in connecting the Bay of Fundy triangulation with that of the province of Quebec.

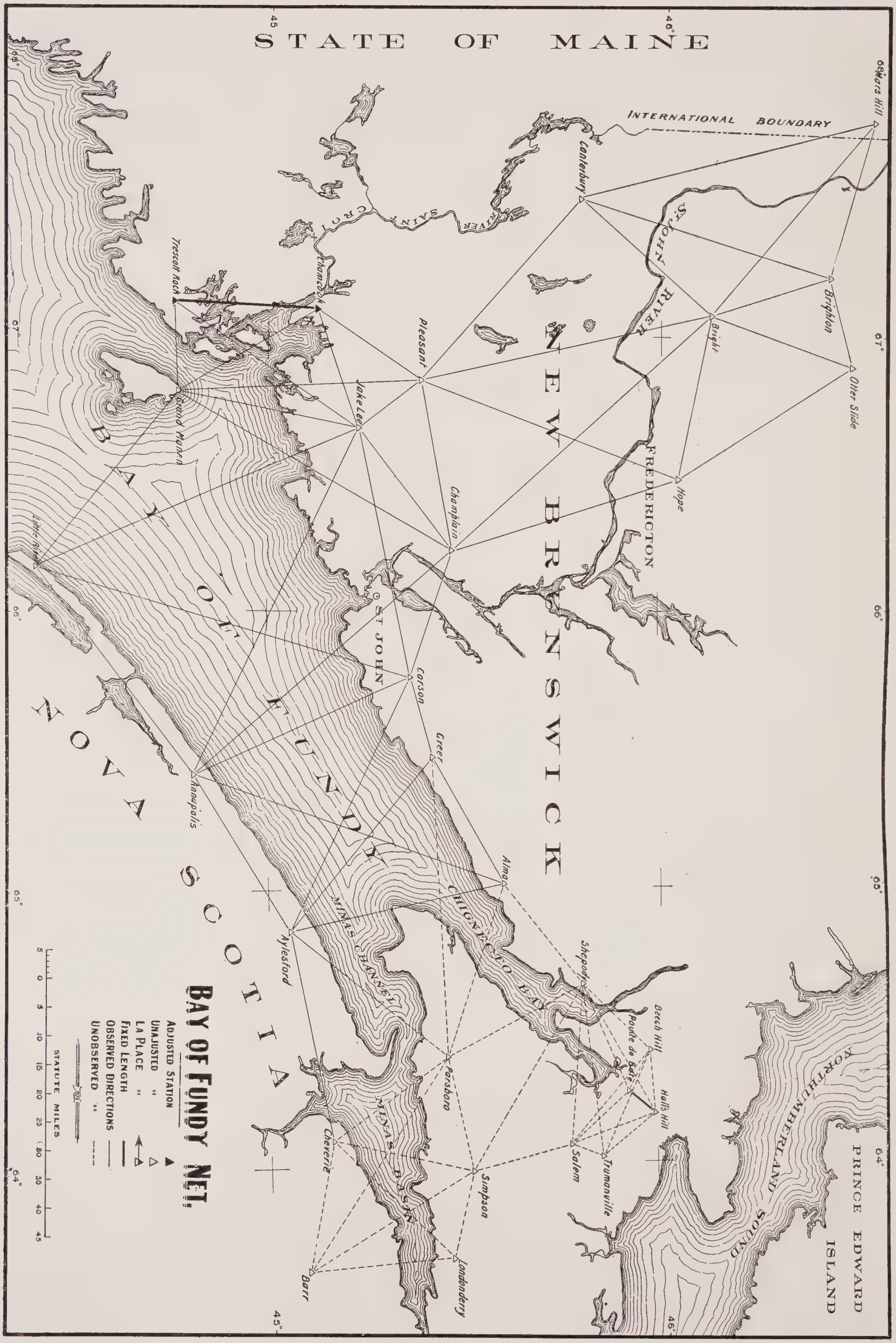
Earlier Reconnaissance.—A preliminary reconnaissance had been made several years ago in this locality by H. B. Kihl, but several of the stations he selected, whose positions he intended verifying and preparing later, were still, in 1917, as he left them, as a result of his transfer to other work.

Scope of Present Work.—Messers. W. M. Dennis and C. H. Brabazon, observers, left Ottawa on May 24 and 22, respectively, for New Brunswick, in order to prosecute the station preparation and observing, northward from the line PLEASANT to CHAMPLAIN, where the observing had terminated the previous season.

Reconnaissance and Station Preparation.—The position of certain of the stations of the previous reconnaissance had to be changed and, on account of the inaccessibility and difficult nature of the country for reconnaissance and station preparation, the part of the season remaining for observing was small.

Observing.—Observing was completed at the six stations, HOPE, BRIGHT, CANTERBURY, MARS HILL, BRIGHTON, and OTTER SLIDE, as shown on the sketch, page 48, after which the remainder of the season was spent on reconnaissance and station preparation.

Extraordinarily wet weather, together with long periods of low visibility throughout the season, caused unusual delays to the work of the party.


STATE OF MAINE
INTERNATIONAL BOUNDARY
NEW BRUNSWICK
NOVA SCOTIA
BAY OF FUNDY
PRINCE EDWARD ISLAND
NORTHUMBERLAND SOUND
CHIGNECTO BAY
MINAS CHANNEL
MINAS BASIN
ST JOHN RIVER
SAINT CROIX RIVER
FREDERICTON
ST JOHN
Mars Hill
Canterbury
Brighton
Bright
Otter Slide
Hope
Pleasant
Chamcook
Trescott Rock
Grand Manan
Lake Lee
Champlain
Little River
Carson
Greer
Annapolis
Alma
Aylesford
Shepody
Beech Hill
Pointe de Bute
Halls Hill
Parrsboro
Salem
Trumanville
Simpson
Cheverie
Londonderry
Barr
BAY OF FUNDY NET.
ADJUSTED STATION
UNAJUSTED "
LA PLACE "
FIXED LENGTH
OBSERVED DIRECTIONS
UNOBSERVED "
STATUTE MILES

PROGRESS OF RECONNAISSANCE IN NEW BRUNSWICK AND NOVA SCOTIA.

OTTAWA, December 13, 1917.

Hazen P. Moulton, Geodetic Engineer, submits the following report covering the field work in southern New Brunswick and Nova Scotia during the past season.

SCOPE

Early in April, 1917, the writer was instructed from your office by the Acting Superintendent of the Geodetic Survey, to proceed to the Mari time Provinces and select a site for a base line and base net for primary triangulation as near as practicable to the line ALMA-AYLESFORD (of the Bay of Fundy triangulation scheme). This base is required to furnish control for the observed triangulation across the bay of Fundy and for proposed triangulation eastward in Nova Scotia.

BASE LINE SELECTED

After making a reconnaissance survey of the country in the vicinity of Amherst and Sackville and also Truro, N.S., it was decided that the best site for a base line was along the Pointe de Bute ridge in Westmorland county, New Brunswick—a short distance from the New Brunswick and Nova Scotia boundary.

This line, now known as the Westmorland base line, is nearly six miles in length, extending in a southwesterly direction from Hall's Hill to Pointe de Bute. It passes over about thirty farms, one mile of the distance being through woodland. A great deal of care was exercised in locating the line so as to avoid all farm buildings and steep grades.

For an expansion of the base on to the primary line SHEPODY-SALEM, two additional stations, BEECH HILL and TRUEMANVILLE were introduced, making a strong net with two quadilaterals on each side of the base. To overcome local obstruction, observing towers about thirty feet in height will be required at SHEPODY, SALEM, BEECH HILL and POINTE DE BUTE.

In the latter part of the season the writer returned to the Westmorland base, opened the line through the woods, and partly prepared it for its final measurement in October. The damage to crops and to woodland in connection with the measurement of the base was very slight, amounting to only thirty-five dollars.

After the selection of the base and net, the reconnaissance for connecting the net to the observed triangulation across the bay of Fundy was completed. The Bay of Fundy triangulation from the line TRESCOTT-CHAMCOOK (a side of the eastern oblique arc of the United States Coast and Geodetic Survey) to the line ALMA-AYLESFORD has already been observed.

Reconnaissance in Nova Scotia

The next work was to carry the reconnaissance eastward to the vicinity of Truro and Pictou, involving the location of several additional stations. Descriptions of all stations have been filed in the geodesist's office. The stations Barr and Camden were selected with a view to carrying secondary triangulation to the city of Halifax.

Fog has been a great hinderance to geodetic work in the Maritime Provinces. The months of September and October have in general been found the most favourable for observing the longer lines.

FIELD REPORT ON BASE LINES.

Ottawa, January 24, 1918.

C. A. Bigger, Assistant Superintendent, makes the following report on the selection and measurement of a base line in L'Islet county, Quebec, the measurement of a base line in Westmorland county, New Brunswick, together with a brief note on the progress of the triangulation of the city of Toronto.

General Method of Base Line Measurement

The errors of observation throughout a triangulation system have a gradually cumulative effect and produce errors in the computed distances between triangulation stations with consequent errors in the computed latitudes and longitudes of these stations. In order that these errors may be detected and corrected, it is necessary to measure the length of one of the triangle sides every couple of hundred miles or so. As the distance between triangulation stations is in general too long and the country too rough to permit of economical and accurate linear measurements being taken, it is customary to select a short line—from 5 miles to 7 miles long—at a suitable site for measurement, and connect this base line with the main triangulation by angular measurements.

In general, it may be said that the base lines of the Geodetic Survey of Canada are measured with 50-meter invar tapes, supported at both ends and in the middle on wooden posts, a constant tension of 15 kilograms being applied to the ends by means of weights to avert an error in the length of the base due to different degrees of sag of the tape. Two thermometers attached to the tapes determine their temperature. Corrections are applied to the measured length of the base due to the various temperatures of the tapes, and to reduce the measured length to the horizontal distance, the final length of the base being reduced to sea level.

The lengths of the tapes are determined before and after a base is measured at the Standardizing building of this Survey. The standardization of the tapes is carried out under the same conditions as to support, tension, etc., as existed during the use of the tapes when measuring the base.

L'Islet Base

Selection of Base Net.—Instructions were received in May, 1917, to select and measure a base near the northeastern end of the Quebec triangulation below Quebec, and on May 23 three men proceeded to St. Jean Port Joli, Que., for this purpose.

A suitable location was found on a tangent of the Intercolonial railway between St. Jean Port Joli, and Ste. Louise, parallel to and about a mile south of the St. Lawrence river, this section being free from any grades or ravines of sufficient size to interfere in any way with the preparation for or measurement of the base. The edge of the railway embankment was chosen as the site for measuring.

In order to make a structurally strong connection between the base and the main triangulation, an extra station was established on Coudres island near the north shore of the St. Lawrence river.

The length of the base was approximately 12·8 kilometers (7·95 miles).

Preparation of the Base for Measuring.—At each 50 meters along the base posts were driven to support the ends of the tape, and midway between each two of these, a smaller post was driven to uphold the middle of the tape up to the line between the two ends. The posts were distributed along the line and the work done with the aid of a handcar on the railway track.

Levels.—Levels were run over the base when weather conditions were unsuitable for measuring. Readings were taken on the tops of the posts supporting the ends of the tape, connections being made to precise level bench-marks whose elevations had been determined by the Geodetic Survey.

Measurement of the Base.—The measuring party consisted of nine men in all—chief of party, two observers, one recorder, two weight carriers and three tape carriers.

Four measures of the base were made, a forward and backward measurement being made with each of two tapes.

Copper strips were attached to the tops of the posts on which scratches were made corresponding to the ends of the tape.

Weather Conditions.—During the measurement of the L'Islet base very little time was lost on account of rainy weather or wind. The prevailing winds blew parallel to the line and were found not to set up enough vibration of the tape to prevent accurate measurements being taken. Measurements taken when a strong wind blew *across* the line were sometimes unsatisfactory, as the measured length was materially shortened by the tape being fluttered and blown off the line. Measuring done during light rains gave good results. Owing to the little time lost on account of wind, the stakes were all set before any measurements were made. This procedure is not generally followed; days when the wind blows too strongly for measurement being used for setting stakes ahead.

Marks at Ends of Base.—The ends of the base were marked alike by an underground and a surface mark. The underground mark consisted of a ¾-inch copper bolt, 4 inches long, with a small hole in its upper face, set with its top level with the top of a bed of concrete 10 inches thick and 4 feet square. This bolt is 6 feet below the ground surface. The surface mark consisted of a

similar copper bolt set in a block of concrete 1 foot square and 5 feet long, with its top extending 4 inches above the ground surface. A thin film of cement covered the surface bolt.

Standardization and Field Care of Tapes.—Before being sent to the field the lengths of the three field tapes were determined at the Geodetic Survey Standards building, and after the measurement of the L'Islet base they were again standardized, and once again after the Westmorland base was measured. The standardization of the tapes was carried on under the same conditions as those under which they were used in the field.

During field operations, vaseline was applied to the tapes each time after they were used, and was rubbed off each time before they were used. The tapes were wound on aluminum reels, 16 inches in diameter. When being shipped, each tape was wound carefully in paper and packed in a box made specially for shipping purposes.

Time Required.—Three men arrived at the scene of operations on May 24 and were occupied till June 12 selecting the base and base net. On June 13 these three men started sharpening, distributing, setting and driving the posts. Labour was very scarce, and, but for this condition, these operations could well have been much hurried by increasing the party on the preparation of the base for measuring. Measurement of the base and levelling occupied the interval from July 6 till July 24, men and boys who lived locally being employed to complete the measuring party. The original three men then built a 40-foot and a 50-foot tower at the two ends of the base, and cut required lines through the timber at connecting triangulation stations. Transportation in this locality is slow and difficult.

Westmorland Base

Selection of Base.—The base had been previously selected in the county of Westmorland, New Brunswick, near the boundary between New Brunswick and Nova Scotia. The length of the base was about 9·8 kilometers (6·09 miles).

Preparation for Measurement.—In general the base crossed farm lands, and considerable cutting of trees and small brush was required to clear the line. The same methods were used in preparing the base for measurement as described for the L'Islet base, except that posts were distributed by wagon and in some places were carried some distance across marshy ground and through woods.

Measurement of the Base and Levels.—The same methods of measurement were used as those described for the L'Islet base. Levels were carried about 4 miles from a precise level bench-mark of the Geodetic Survey on the Intercolonial railway.

Weather Conditions.—Very unfavourable weather conditions existed during the preparation and measurement of the base, high winds and rain making the progress of the work very slow.

Marks at Ends of Base.—East base is marked by a ¾-inch bolt, fox wedged and leaded into the rock and referenced by three similar bolts. West base is marked in the same manner as the ends of the L'Islet base.

Standardization of Tapes.—The lengths of the tapes were determined before and after the measurement at the Standardizing building of this Survey at Ottawa.

Time Required.—On September 4 a party consisting of a chief of party and three assistants commenced preparing the line for measurement. Measurement of the base occupied the time of the party from October 7 to October 23. Only while the measuring was in progress was extra help employed.

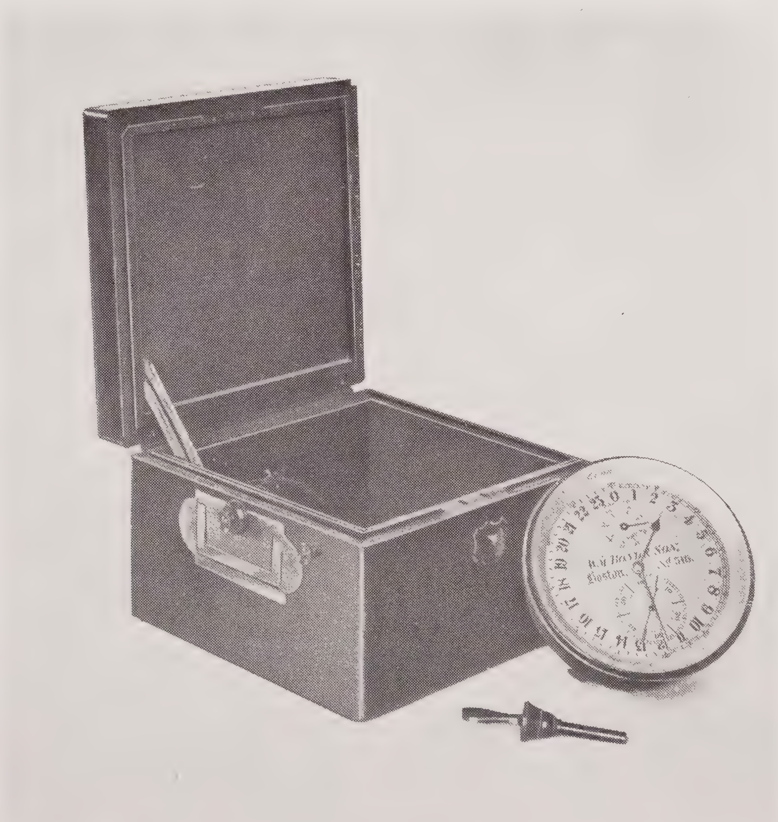
Triangulation of City of Toronto

On November 5 the writer resumed work in the vicinity of Toronto—begun in the autumn of 1916—having for its object the connection of certain points in the city of Toronto with primary triangulation stations of the Geodetic Survey of Canada.

This survey consists of measured transit lines projected on the east, north and west of the city from which angles are determined to Scarborough Geodetic Survey station and also to many steeples, flagstaffs and turrets on permanent structures within the city, sufficient to form a skeleton map on which an accurate triangulation of the whole city may be based.

The transit lines are being perpetuated by monuments of a permanent nature, which will be used by the city of Toronto and its suburbs for the construction of accurate maps and for checking their surveys.

This work is carried on by the writer and one assistant resulting in the accumulation of most valuable data at a comparatively nominal cost.



Sidereal Break Circuit Chronometer, Bond 516.

ASTRONOMIC WORK AND TAPE STANDARDIZATION

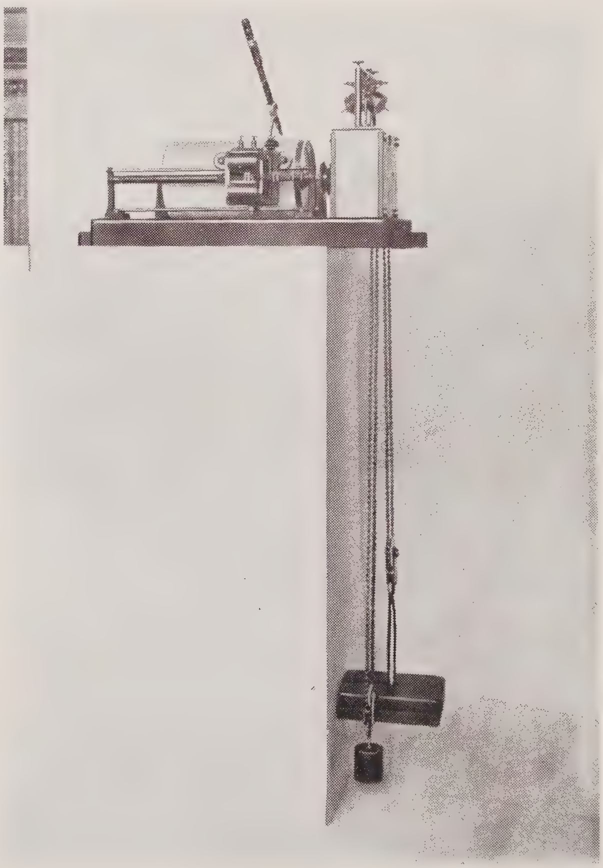
OTTAWA, January 21, 1918.

F. A. McDiarmid, Geodetic Astronomer, submits the following descriptive report of the astronomic work, and the standardization of the invar field tapes, carried on by him or under his supervision the past summer.

ASTRONOMIC WORK

During the past summer, between May 28 and September 17, observations were made for longitude at two geodetic points, COLLINGWOOD and SOUTHWOLD in western Ontario, and at one point, POUCE COUPÉ, in British Columbia near the British Columbia-Alberta boundary line.

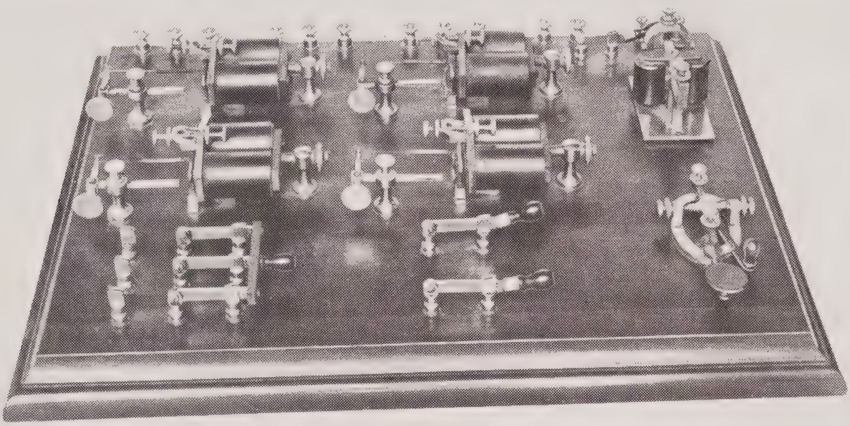
The azimuth of the line connecting the geodetic point at COLLINGWOOD to STAYNER WEST BASE was observed; that of the line from SOUTHWOLD to WESTMINSTER was also observed.



Field Chronograph.

The observations for longitude and azimuth at stations COLLINGWOOD and SOUTHWOLD were taken to control the twist of the triangulation system at these stations, while the station at POUCE COUPÉ was established for the purpose of determining the 120th meridian, the boundary line between British Columbia and Alberta. Latitudes were observed at SOUTHWOLD and POUCE COUPÉ, the latitude of COLLINGWOOD having been determined in 1916.

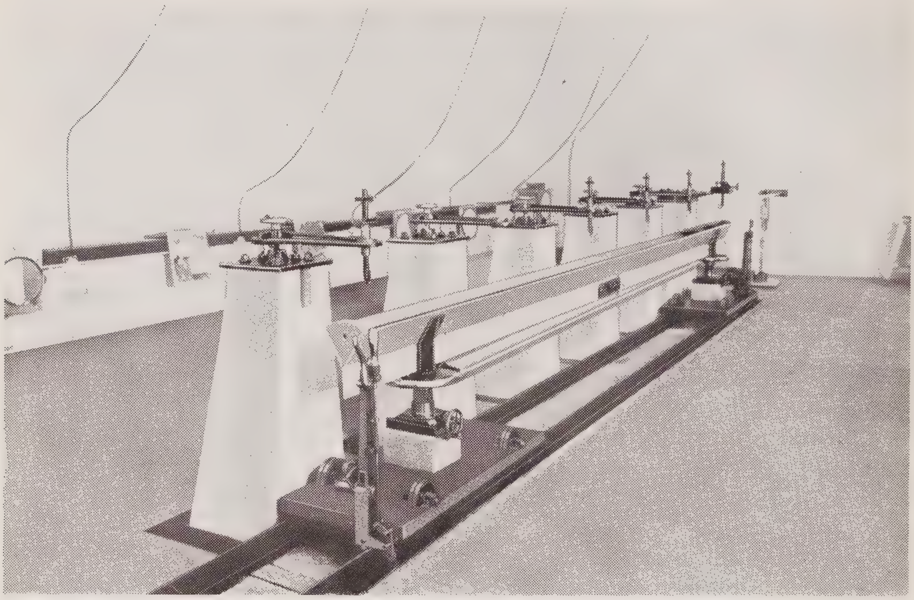
At COLLINGWOOD six determinations of longitude on different nights, and twenty-four determinations of azimuth on four nights, were made. The whole time spent at this station was thirteen days, a good deal of cloudy weather being encountered. An attempt had been made in 1916 to occupy this station, but



Switchboard, providing connections for Exchange of Clock Signals and Recording of Star Transits.

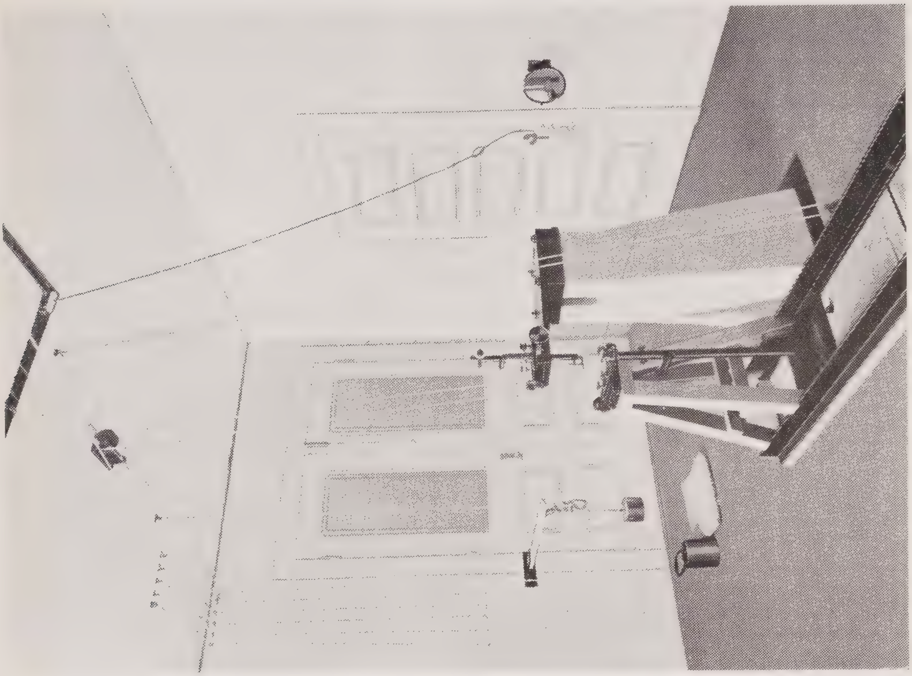
bad weather in the late fall compelled the abandonment of the work. After the abandoning of the astronomic work in 1916, the observing tower was built over the astronomic pier, and when an attempt was made to re-occupy the pier in 1917, it was found that the tower shut off the light from the time stars. A second pier was built slightly west of the old pier. Thus both azimuth and longitude observations were made on the same night. In this way the observer was saved the labour of special time observations for his azimuth work.

The SOUTHWOLD astronomic station is 17 feet from the SOUTHWOLD geodetic point. Five nights longitude observations were made, on the first four of which latitude was also observed. On the fifth night after finishing the time work, the transit was removed from the pier, and the azimuth instrument mounted. The rest of that night and the next night were spent in determining the azimuth of the line SOUTHWOLD to WESTMINSTER. The observations at SOUTHWOLD were commenced on the evening of June 28, and finished on the night of July 4. During these seven nights, five determinations of longitude, seventy determinations of latitude, and seventeen determinations of azimuth were obtained. The weather was nearly perfect, only one cloudy night occurring during the period.

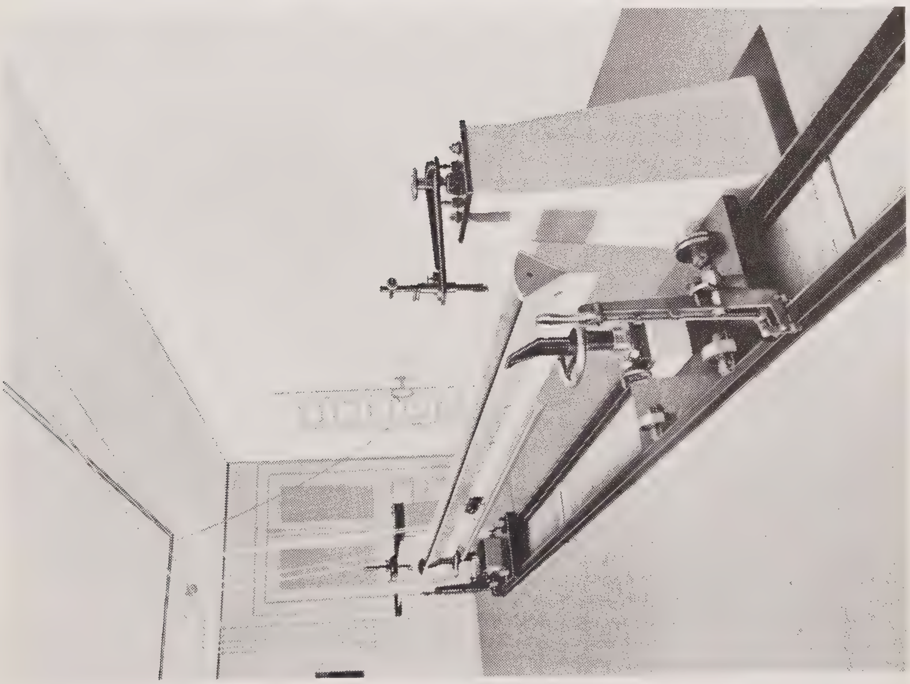


In the Standardizing Building at Ottawa, showing the 5-metre Base at the north end of the Comparator, with the Trough holding the 5-metre Steel Bar and the Standard 1-metre nickel bar.

Base Line Measurement, showing Straining Bar and Weight for Applying Tension to the Tape during Measurement; also showing the Tape Reel.



In the Standardizing Building at Ottawa, showing the Cut-off at the south End of the 50-metre Comparator and a Tape suspended by a weight.



In the Standardizing Building at Ottawa, showing the 5-metre Steel Bar in the Trough at the south end of the Comparator.

The determinations of longitude and latitude at Pouce Coupé, B.C., took considerable time. The trip from Ottawa to Edmonton took three days, and from Edmonton to Pouce Coupé four days. The observing party left Ottawa July 15 and reached Pouce Coupé on the 24th. The work was finished on the evening of the 15th of August. A great deal of difficulty was experienced in getting the time signals through from Ottawa.

The telegraph line from Edmonton to Pouce Coupé runs for nearly eight hundred miles through a rough broken country. A heavy rain which lasted several days sufficed to break and ground the wire in many places. For a period of nearly two weeks it was impossible to get connection from Pouce Coupé to Edmonton. However, finally, seven determinations of longitude on five nights were obtained. About seventy determinations of latitude were made at Pouce Coupé.

Personal equation was determined at Ottawa in May before observing at Collingwood, in July after observing at Southwold, and in September after returning from Pouce Coupé. The personal equation, which was found to be nearly eight one-hundredths of a second of time, is so large as to make its determination very essential.

Standards Work

The work carried on in the Standardizing building was as follows: In April and May the lengths of three field tapes, Nos. 3139, 3140 and 3141, and the two reference tapes No. 4252 and No. 13814, were all determined from the standard nickel bar No. 10239. The five-metre bar was used in stepping up from the one-metre bar to the tapes. In making all observations with the bars, they were placed in an ice-and-water bath, particular care being essential to secure both bars at zero degrees, Centigrade. Experience has shown that both bars should be in ice and water at least forty-eight hours before starting observations.

In September, after the measurements of the L'Islet base line, the lengths of the tapes were again determined, and also in November after the measurement of the Westmorland base.

The lengths of the 5-metre bar at 0° C. and the five invar tapes at 16·5° C. as determined are given in the following table:—

Lengths in Metres from Standard Metal Bar No. 10239

Date.	5-Metre Bar.	Tape 4252	Tape 3139	Tape 3140	Tape 3141	Tape 13814
1917						
May	4·9999490	50·000604	49·999762	50·000316	50·000732	50·000461
September	4·9999499	50·000577	49·999687	50·000212	50·000630	50·000403
November	4·9999499	50·000578	49·999623	50·000216	50·000582	50·000464

PRECISE LEVELLING IN 1917

OTTAWA, November 14, 1917.

F. B. Reid, Supervisor of Levelling, submits the following progress report upon precise levelling operations during the season of 1917.

Three parties were in the field in charge of Messrs. McMillan, Rainboth and McGrath.

LEVELLING BY D. MCMILLAN

This party left Ottawa on April 23 for Boissevain, Man., and commenced levelling at that point on the 27th. A line of levels was extended in a south-easterly direction along the Great Northern railway to the international boundary for the purpose of checking the levelling along the boundary.

After finishing this the party moved to Napinka, Man., and levelled along the Canadian Pacific railway to Neepawa via Kemnay, Brandon, Chater and Minnedosa, levelling being discontinued at Neepawa on August 14. The balance of the season was spent in working on a line from Sprague to Neepawa, via Winnipeg. This line was too long to finish, however, and work was discontinued on October 20 at a point 11·8 miles west of Winnipeg. The Canadian Northern railway main line was followed from Sprague to Winnipeg, and the Canadian Pacific railway main line west from there. When this line is completed to Neepawa it will close a circuit and thus form a check on the levels run in 1910 and 1911 paralleling the international boundary from Emerson to Napinka.

Wind is the worst enemy of precise levelling on the prairies, and Mr. McMillan reports an unusually windy season; as a consequence the mileage covered was not so great as has previously been covered in more favourable seasons on the prairies. A railway motor car in place of a hand car was used for the greater part of the season, and proved of great assistance.

LEVELLING BY A. J. RAINBOTH

This party left Ottawa on April 18 for Kamloops, B.C., and commenced levelling on the 30th, the line being a continuation of the line from Abbotsford which was begun in 1915. It had been extended by Mr. McMillan in 1916 to a point about 17 miles north of Kamloops junction. Mr. Rainboth now carried the line through to its terminus, 1½ miles east of Resplendent, following the Canadian Northern railway. At this latter point it was closed on one of the bench-marks previously established by N. H. Smith in his work along the Grand Trunk Pacific railway.

The balance of the season—from August 17 to October 19—was spent on the main line of the Grand Trunk Pacific railway in continuing the levels westerly from mileage 1,153 west of Winnipeg (the end of 1916 work by N. H. Smith) to the town of Prince George (mileage 1,281 west of Winnipeg).

At a Bench-mark in a bridge abutment on the Canadian Pacific railway near Banff, Alta.

Bench-mark at the entrance to a tunnel on the Grand Trunk Pacific railway near McBride, B.C.

Levelling by W. N. McGrath

This party left Ottawa on April 23 and proceeded to Montreal. Starting levelling at St. Lambert, on the 26th, at a bench-mark of the Rouse Point–Sherbrooke line, they carried levels across the Victoria bridge over the St. Lawrence river, thence along the Grand Trunk railway tracks through St. Henri and along Atwater avenue (Montreal) to the Canadian Pacific railway tracks near the Windsor Street station. From this point the above tracks were followed through Montreal West and around through Mile End to the Place Viger station; the city streets along the water-front were then followed till the line closed on itself at the bench-mark at the end of the Victoria bridge. This loop-line around the city of Montreal (length, without branches, about 22 miles) should be of considerable value in future city development work; nineteen of our standard bench-marks were established along its course, and four permanent bench-marks of the Public Works Department were tied in.

Levels were then run along the Canadian Pacific railway north shore line from Mile End towards Hull, with a branch line (requested by the Militia Department) from St. Martin junction to Three Rivers. Owing to the slow progress made by this party all through the season, the levels on the north shore line did not reach Hull, but were discontinued for the season, on October 31, at Papineauville.

Inspection of Bench-Marks and Revising Descriptions by F. B. Reid

Following out the previously established policy of inspecting all bench-marks and correcting and revising their descriptions before publication of the results, three trips of inspection were made during the season. The railway motor car belonging to the Survey was utilized on this work, and by its use an aggregate distance of some 1,550 miles was covered.

Between June 8 and 19 all bench-marks established by H. P. Moulton in Quebec in the 1916 season were inspected; this included also the last part of G. F. Dalton's 1915 work. In August and the first part of September a trip was made to the West, and an inspection made along the following lines: Abbotsford to Resplendent, B.C., Revelstoke to Kamloops, B.C., Jasper, Alta., to McBride, B.C., and Port Arthur to Franz, Ont.

Between September 17 and 25 all bench-marks established by W. N. McGrath in western Ontario in the 1916 season were inspected. In all, 470 bench-marks were inspected during the summer, and each of the three levelling parties was visited in the field.

Summary of Field Work

The mileage levelled (run in both directions) is shown in the following able, also the percentage of re-levelling by each leveller, the number of standard

bench-mark piers built and the total number of bench-marks established, including piers.

Leveller	Mileage levelled	Mileage re-levelled	Piers built	Total Bench Marks established
D. McMillan	253	$3\frac{1}{2}\%$	12	60
A. J. Rainboth	339	$9\frac{1}{2}\%$	14	90
W. N. McGrath	188	$17\frac{1}{2}\%$	2	78
Total	780	....	28	228

Summary of Lines Levelled in 1917

Line	On railway	Branches	Total
Boissevain to Bannerman, Man. (International Boundary)	21·2	0·7	21·9
Napinka to Neepawa, Man	119·5	5·9	125·4
Sprague to 11·8 miles west of Winnipeg	103·4	2·0	105·4
Mileage 17·3 north of Kamloops junction to Resplendent, B.C	211·0	0·0	211·0
Mileage 1,152·8 west of Winnipeg (G.T.P. Ry.) to Prince George, B.C	127·9	0·0	127·9
Montreal loop-line	21·6	3·4	25·0
Mile End to Papineauville, Que	73·7	1·3	75·0
St. Martin junction to Three Rivers, Que	82·0	6·2	88·2
Total	760·3	19·5	779·8

The map on page 64 shows the lines of levelling run during and previous to the present year.

Publication of Results.

In the month of February a publication was prepared giving descriptions and elevations of bench-marks, etc., for lines covering an aggregate distance of some 1,703 miles; included in this publication were an additional 842 miles of republished levelling—originally published in the Chief Astronomer's report for the year 1910—making a total of 2,545 miles. Publications similar to this year's have been issued each winter since 1913, the miles of levelling covered by each publication being as follows:—

	Miles.
1913	2,004
1914	1,156
1915	1,156
1916	1,624
1917	2,545
Total	8,484

INDEX

Precise Levelling, Published.
Precise Levelling, Not Published.